Prolonged Care

Prolonged Care

Edited by

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Borden Institute
US Army Medical Department Center and School
Medical Center of Excellence
Fort Sam Houston, Texas

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THE FIRST UNITED STATES EDITION

of

PROLONGED CARE

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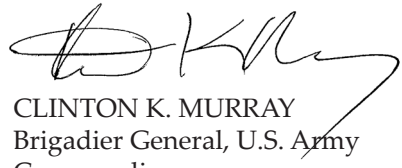
Foreword

Army medicine has a phenomenal history of adapting and innovating the profession to provide world-renowned life-saving treatment under all conditions for warfighters. The dedicated medical community—from combat medics to trauma surgeons—always rises to the occasion and is challenged to do so again. It is anticipated that evacuation times will increase in future near-peer conflicts. When evacuation is planned but delayed, demands on prehospital medical personnel and resources at Roles 1 and 2 will escalate.

Prolonged Care fills the knowledge gap in essential care provision, for approximately 6 to 72 hours, after the initial life-threatening injuries are stabilized and before a casualty is evacuated to a higher role. It provides a missing component in the continuity of care from the point of injury to definitive care. Several published books detail care before and after the prolonged care treatment window. For example, required topics for early care are covered in medic handbooks, including the Ranger Medic Handbook and the Tactical Combat Casualty Care guidelines; later care is covered in books such as *Emergency War Surgery*. However, none of the books are specific to prolonged casualty care.

I am honored to present the first edition of Prolonged Care. This groundbreaking effort consolidates information gleaned from Special Operations Forces and other military medical providers who have accepted the challenge of providing life-saving care on the ground when casualty evacuation is delayed. I'm proud of all our skilled and creative medical professionals who made this important and timely book possible.



CLINTON K. MURRAY
Brigadier General, U.S. Army
Commanding

Introduction

In our role as military medical professionals, it is our profound duty to understand history and improve upon what we have been given to maximize patients' care, survivability, and functional ability during and after conflict. We have known for millennia that the care of the wounded in remote areas is a significant knowledge gap, and for centuries these wounded were left to die. However, until this publication, we have done little to collectively improve the doctrine associated with prolonged field care. Ever since MAJ Letterman set up a system of triage and rearward evacuation in the Battle of Antietam, we have focused tremendous energy, research, training, and doctrine development around the rapid evacuation and care of the injured on battlefields around the world. Life-saving advances in pain management, blood transfusions, damage control surgery, antibiotic stewardship, airway management, and hemorrhage control have led to remarkably low died of wounds rates and unparalleled survivability. But standardizing the approach to prolonged field care has not been prioritized. We learned much from our conflicts in Vietnam, Desert Storm and Shield, and Operations Iraqi and Enduring Freedom. We doctrinalized the Golden Hour of trauma care. We relied on total air superiority to rapidly evacuate and provide en route transit care for our most critically wounded. But it was often left to the front-line medic, Special Forces physician assistant, or other far forward detached provider to develop how to prolong life when in austere environments. The chapters in this book are meant as a guide to help you develop the casualty care plans for your unit. Relying on experts across military medicine, they have done their best in capturing lessons learned and codifying them into this first edition of Prolonged Care.

We hope this edition is rapidly succeeded by a second and third edition, as we continue to improve our knowledge and training associated with this critical subset of our patients. Let us hope

that we never have to practice any of these techniques or skill sets, but if we do, that we are well trained and equipped to bring our young men and women home alive.

BRIAN C LEIN, MD
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Chapter 1

DEVELOPMENT OF PROLONGED CARE

Sean Keenan, MD

Introduction

Prolonged care (PC) is not new. The concept most likely described the standard for military and austere medicine for the first half of the 20th century. Managing serious and critical casualties in austere environments, with limited supplies and medical personnel lacking specialization or clinical experience (compared to modern standards), was the reality, especially during times of armed conflict.

Background and Development

For the first part of the 21st century, the US military focused on the conflict known initially as the Global War on Terrorism. In deployed settings in Southwest Asia, the military built the most comprehensive and effective deployed expeditionary trauma care system in the history of warfare. Through considerable effort, support, and overall experience, we observed the lowest mortality rates in the history of warfare. As a result, the prehospital phase of care was hyperfocused on the "first aid" of combat trauma, perfecting the protocol for tactical combat casualty care (TCCC). Combat units' predeployment medical training and education became defined by TCCC—to the exclusion of all other practice. This narrow focus of education and training set the stage for challenging this prehospital paradigm with the consideration of other operational situations, primarily those experienced by Special Operations Forces (SOF).

Though most medical focus was necessarily on TCCC, SOF were deploying to other geographic areas where the operational reality of rapid life-saving care and quick medical evacuation

was challenged by resource-limited areas and evacuation times orders of magnitude longer than assumed for standard operational doctrine. No other theater provided a starker contrast to Southwest Asia than the operations in Africa. Members of the SOF community saw a need to shift focus to other medical situations and formed what would become the Prolonged Field Care (PFC) Working Group (WG) in late 2013. NATO SOF forces had met earlier that year and defined the term "prolonged field care," which the US-based PFC WG adopted.

In an attempt to quantify and qualify the operational setting, the WG took a bottom-up approach to describing the situation, framing it in terms of broad capabilities and operational contexts, and identifying gaps in patient care in austere environments (detailed in the first two position papers and later published). The Joint Trauma System (JTS) supported these efforts, and subsequent clinical practice guidelines (CPGs) addressed these observed gaps in traditional prehospital literature.

As a means of distributing the best practices and JTS CPGs, the WG established a website and educational podcast to inform the medical community (https://prolongedfieldcare.org). A core of SOF medics pursued this service, and it eventually received funding and sponsorship. Later, it also received support from an educational nonprofit company. Following lessons on the use of civilian social media and free open-access medical education, the grassroots effort quickly gained favor and became an unofficial conduit of information for a diverse operational problem set. In fact, these online efforts were identified as a best practice, and other organizations, most notably the JTS, stood up their own online presence. The JTS website is https://deployedmedicine.com.

Though PFC originally described the operational environment characterized by prolonged evacuation times, the US Army and other services saw analogs through the study of future threats. The concept of large-scale combat operations (LSCO) describes a lack of air superiority and disrupted supply and evacuation lines. Through analysis, operational planners recognized that the SOF concept of PFC described the medical situation of LSCO. In addition, with the global pandemic of COVID-19

beginning in early 2020, the medical community presented an analysis and adoption of a Crisis Standards of Care policy, which acknowledged the need for a set of guidelines not unlike the resource-limited guidelines initially presented by the PFC WG. This synergy, with initially diverse operational and contingency situations, exemplified the utility of a broader adoption of PFC methodology. In 2021, the JTS Defense Committee on Trauma officially chartered a working group under the name Prolonged Casualty Care (PCC). The PCC WG published a set of guidelines specifically for the conventional military forces, following the best practices of the prehospital TCCC protocol, and intended for adoption by all services.

Summary

Regardless of the name or service describing the need today, the core concepts, capabilities, and operational context initially considered in 2013 by SOF under the moniker of "PFC" holds particular relevance to medical care provided in contingency, austere, and resource-limited settings. Though this is intentionally intended to be a contingency or "Plan C" strategy for medical care, the concepts are broadly applicable to a wide variety of medical situations outside the normal, mature medical system structure.

Chapter 2

PROLONGED CARE PRINCIPLES AND PRACTICAL SOLUTIONS

Paul Loos, 18D, SO-ATP; Jamie C. Riesberg, MD; and
Michael Remley, NRP, SO-ATP

Introduction

The principles and strategies of providing effective prolonged care (PC) help organize the overwhelming amount of critical information into a clear clinical picture and proactive plan, regardless of injury or illness. In-hospital critical care is traditionally provided by a multidisciplinary team of specialists working together to produce the best outcomes. Prolonged care will occur in suboptimal environments and require providers' best care without the usual benefits of a developed healthcare system, including the timely transfer of critically ill or injured patients. The PC concept originated in 2014 with Special Operations Forces (SOF) as prolonged field care (PFC) and was adapted for the non-SOF medical forces as prolonged casualty care starting in 2020. The term has since evolved to prolonged care (PC). PFC uses 10 core capabilities based on the higher level of medical training SOF medics receive. On the other hand, PC is based on the tactical combat casualty care (TCCC) role-based training and certification skill levels that endow all service members with the knowledge to act and contribute to patient care.

Key Principles

- The foundation of good PC is mastery of TCCC combined with strong clinical medicine skills.
- Care must be provided even with limited personnel, experience, supplies, and equipment.
- Monitoring trends in vital signs and assessing casualties must be completed at regular intervals.
- Consider telemedicine early.
- Develop an adaptable care plan that can both drive and respond to changes in patient status, environment, or evacuation.

Approach

Within an intensive care unit, integrated caregiver teams make decisions and perform tasks as part of a system of systems. This system is heavily augmented with technology, including active and passive monitoring systems, dedicated and rotated staff who are specially trained and experienced, and specialized team members from other domains (eg, pharmacy and speech therapy). When questions arise, others are available for consult via telemedicine from within the institution or associated facilities dedicated to their support.

PC enjoys none of the benefits of in-hospital critical care; the medic providing care lacks the advantage of a comprehensive team, the proper equipment, sufficient clinical experience, or adequate facilities. Due to the lack of surgical assets, higher capability medical assets denial, and the dispersed nature within the full range of military operations, most medical plans will include PC as a contingency. Unplanned PC happens when medical capacity or capability is overwhelmed due to external factors such as the tactical situation, environmental constraints, and social or political sensitivity.

Telemedical consults should be near the top of the list for any medic in the PC planning and preparation phase, as part of the multidisciplinary response to injury prevention, care, and rehabilitation. The receiver of the telemedical call and the sender require training for maximal effectiveness. Medical providers must understand their situational limitations in equipment, experience, or training to capitalize most efficiently on the benefits of telemedical consults. Some established standards of care, provider capabilities, and facility capacities can be replicated in a rudimentary fashion to increase patient outcomes if properly trained and rehearsed. Nursing care plans, consults for specialty care, and patient handoffs or transfers are all based on hospital best practices but will be significantly different in the PC environment.

Patient Documentation

Problem List and Care Plan

After providing initial care and stabilization of a trauma or medical patient, perform a detailed physical exam and history

to facilitate a comprehensive problem list and corresponding care plan. The problem list and care plan are small but powerful parts of patient documentation.

Each patient presents with immediate physical and mental care requirements, but anticipating the next steps and creating a care plan is essential. This organized and proactive approach improves patient care, particularly in a PC setting. Every treatment has a potential consequence and should be included when anticipating the patient's needs. Therefore, the care plan should address all illnesses and injuries, all invasive treatments, and any treatments that could cause problems later. A complete care plan will also help medical providers avoid iatrogenic injury, which adds to the patient's physiological burden. For example, a longer-term care plan will record that the patient has an IV and include instructions to clean and monitor the site for signs of infection.

Trend Analysis

Vital sign trending is the next documentation that affects the care plan. Begin trending with the earliest vital signs taken and continue at regular intervals to compare baseline measures with the patient's current state. Done graphically on a flow sheet or other medium, a trend line that might otherwise be lost in a jumble of numbers may become apparent. Along with serial physical exams, trends can help the medic anticipate the patient's physiological trajectory and identify patterns indicating specific pathology. For example, Beck's triad (low blood pressure, jugular vein distension, and muffled heart sounds) may suggest fluid around the heart, or pericardial tamponade. Lab results augment trend analysis and physical exam findings when available and can confirm or rule out diagnoses.

Objective Decision Making

Dispassionate and objective decision making is critical when providing PC. A lone medic providing care to a critically ill patient is particularly susceptible to bias. The danger of bias is that it will result in more work for that medic or more risk due to uncertainty or lack of familiarization with a specific

procedure. If the person making the decision is the same person responsible for performing the work, it is easier to rationalize the work away, leaving the patient wanting for the procedure. For example, if a medic thinks that a patient needs a fasciotomy, they may also think of reasons why the patient would not need that procedure or that performing it might worsen the situation. This same cognitive dissonance is encountered when deciding to perform a cricothyroidotomy and then performing it properly and in a timely fashion. Evidence-driven training is imperative to help medics reduce bias and avoid sub-standard care when the time comes to make difficult decisions. Telemedicine can augment this process and solve the conundrum by using a dispassionate, outside voice for reassurance and to help diffuse the responsibility for complications that may arise.

Prolonged Care Procedures

The following actions can be implemented in any austere environment, from dispersed small-team operations in permissive environments to large-scale combat operations, to make the care of a critically ill patient more efficient for the medic and his team. These mimic the systems and processes in typical intensive care units without relying on technology.

Roles and Responsibilities

Ideally, team roles and responsibilities are determined before a crisis requiring PC. Then rehearse as much as possible in as realistic an environment as possible. Some suggested roles, depending on the size of the team, may include:

- Operational team leader.
  - This individual (medically trained or not) must be cognizant of the overall situation outside of the clinical situation and be willing and able to make decisions when required.
  - The team leader's overarching goal should be the safety and well-being of the team members who may be immersed in patient care.
  - This person may also coordinate evacuation assets, relay operational updates, and request resupply.
- Medical team leader.

- This individual is responsible for making decisions on the priorities of medical care.
- The team leader's goal is to remain objective in making the most effective decisions based on the patient's current situation.
  - Objectivity is best accomplished by physical removal from active patient care, even by just a few feet, and avoiding the urge to be drawn into physical tasks.
  - If the medical team leader is the most experienced person in a specific, high-risk task (eg, placing a definitive airway), they should direct the preparation of equipment and medication, step in and perform the procedure, and then back out and relinquish the responsibility of the remainder of the physical tasks.
  - If there is an appointed recorder (best practice), this person should physically and verbally remind the medical team leader to back off and resume control of the entire situation.

- "Head" person.
  - This is an experienced medical provider who is physically present at the head of a patient who is unconscious or requires deep sedation.
  - This provider continually reassesses the patient's status by checking the airway, level of sedation, and vital signs.
  - Widely utilized tools such as the Richmond Agitation and Sedation Scale, graphical flow sheets, and technological adjuncts like digital monitors and metered IV administration pumps can help make this job easier for the head person and safer for the patient.
- Procedural technicians.
  - These individuals are trained to perform specific tasks. They are not required to understand the patient's pathophysiology and may be trained in certain recurring tasks as they gain experience.
  - The training of non-medical team members in simple tasks such as taking and recording vital signs, certain aspects of nursing care, or other menial work can significantly alleviate the burden and allow the more knowledgeable team members to focus on more complex tasks.

  - These technicians should be aware of their limitations and be comfortable with seeking additional assistance.
- Remote telemedical consultant.
  - As of this writing, the US DOD Advisor line is staffed 24 hours per day by an operator who can connect the medical care team to a host of trained, remote consultants in many different specialties.

Note: If working with a new team as a crisis unfolds, deconflict roles and responsibilities as soon as possible to avoid duplicating or paralyzing efforts due to fear of overstepping boundaries.

Without a dedicated helpline, a medical provider can set up their own telemedical consultation with a trusted provider or team before deploying into an austere or resource-limited environment.

Medical Care and Documentation

The goals for proper medical treatment and incremental gains in the patient's status keep the team motivated to do the small things properly now and avoid complications later.

- Perform initial lifesaving care using TCCC guidelines and continue resuscitation.
- Prepare documentation for patient handover. Begin preparation for evacuation immediately upon assuming care for the patient by sending hasty and detailed evacuation requests up both the medical and operational channels. The goal is to get the patient to the proper role of care as soon as possible.
- Perform a comprehensive physical exam, a detailed history, a problem list, and a care plan (Figures 2-1 and 2-2) after the initial care and stabilization of a trauma or medical patient.
- Record and trend vital signs on a dedicated trending chart (Figure 2-3). Begin with the earliest set of vital signs taken and continue at regular intervals to compare the baseline values to the current reality.

- Perform a telemedical consult as soon as is feasible. Prepare a telemedical consultation by filling out a preformatted script or writing down medical concerns and the latest patient information (Figures 2-4 and 2-5).
- Create a 24-hour nursing care plan (Figure 2-6).
  - Address nursing care and environmental considerations early to limit iatrogenic injury and ensure continuous care.
  - Customize the nursing care chart for each patient through the included prompts, via telemedical recommendation, or according to the expertise of the provider on site.
  - Once a critical recurring task is recognized, highlight that task across the entire sheet for the interval required. Verify completion by signing off with the care provider's initials.
- Implement a team work schedule using rotations for rest, food, and mental decompression.
  - Base the schedule on the timeline, the number of competent personnel, and the complexity of the patient.
  - Post a roster. The team leader works with the medical leader to enforce all members receiving breaks. The caregiver and each of the assistants must take care of each other.
  - Use remote consultants if devices are available to transmit vital signs in real time to a team in a less stressful environment.
  - Include a posted set of orders that everyone on the team understands so that the primary provider can get rest without too much worry. This can include specific orders such as "Wake up Doc" if the monitor alarms, if the heart rate exceeds x beats per minute, if changes in mental status are noticed, if there is a drop in systolic blood pressure, etc.
- Anticipate resupply and electrical issues.
  - Keeping equipment charged and ready for receiving a patient is obvious and usually considered in planning an austere deployment.
  - Maintain multiple means of charging any items deemed critical to the mission. Options include:
    - Local power with a local surge protector inverter and power strip.
    - Solar panels and battery.
    - A generator or a vehicle with a robust inverter.

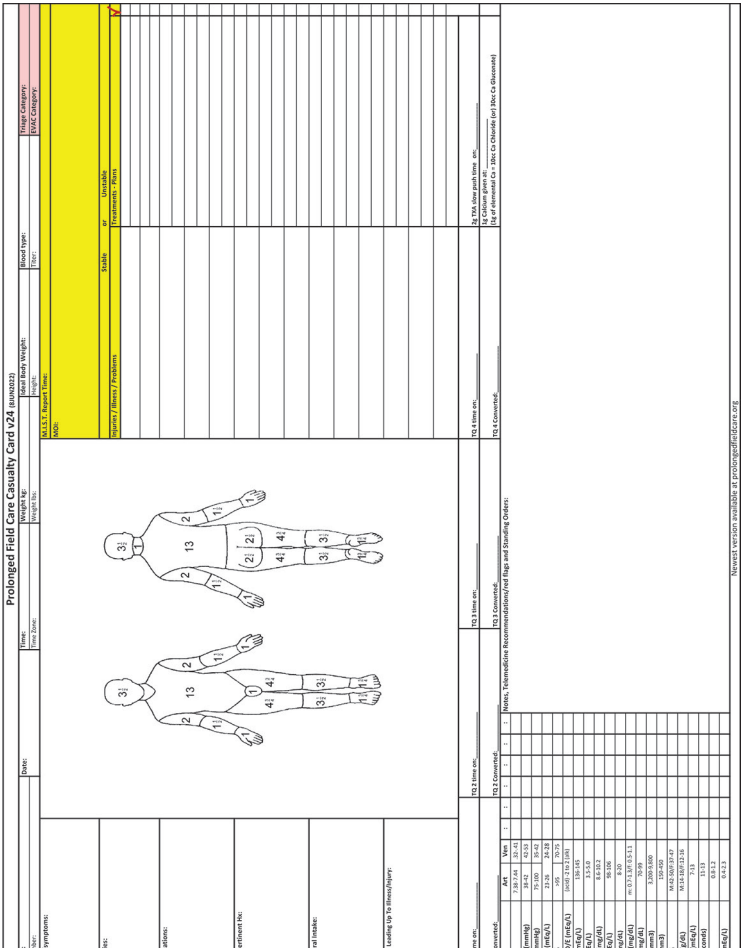


Figure 2-1. The front of a prolonged field care casualty card. Reproduced with permission from the prolongedfieldcare.org website. Published June 8, 2022. Accessed February 8, 2023. https://prolongedfieldcare.org/wp-content/uploads/2022/06/PFC-Flowsheet-v24-final.pdf

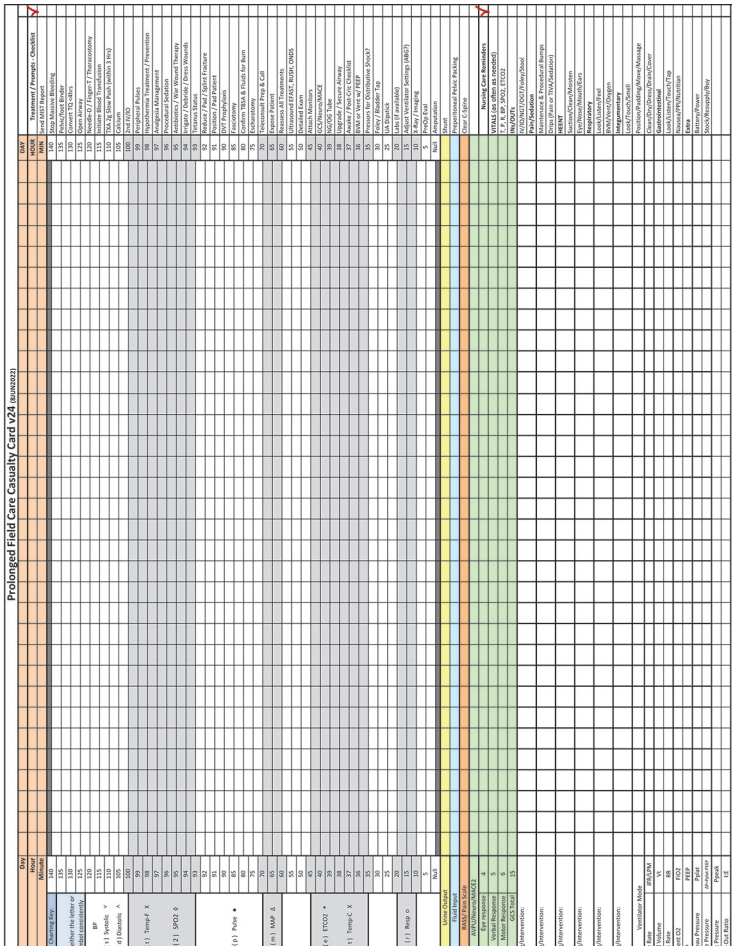


Figure 2-2. The back of a prolonged field care casualty card. Reproduced with permission from the prolongedfieldcare.org website. Published June 8, 2022. Accessed February 8, 2023. https://prolongedfieldcare.org/wp-content/uploads/2022/06/PFC-Flowsheet-v24-final.pdf

PFC Basic Vitals Chart Chart vitals here first then trend on the PFC FLowsheet										
Time	Pain/LOC AVPU/GCS	Resp Rate	EtCO2	Pulse Ox	Heart Rate	Blood Pres	MAP= $\frac{Sys+2Dia}{3}$	Shock Index= HR/Sys	Temp	UOP
1256 L	GCS 12	18	38	95	110	90/60	70	1.2	97.2 f	40 mL

Figure 2-3. A sample basic vitals chart for prolonged care. It may be customized to meet the user's needs. Chart courtesy of Paul Loos, Sergeant First Class, US Army Special Operations Command.

  - If no inverter is available, device use can be rationed during critical times.
  - If you are not actively looking at a patient monitor or device and not using it for an alarm, consider turning it off to conserve power between uses.
  - Be familiar with the state of your batteries. Some batteries left in devices for too long may only last minutes when unplugged.
  - Read the manufacturer's recommendations on properly charging and discharging batteries before inadvertently ruining the battery's life.
- Perform periodic mini-round assessments. Stepping back from the patient's immediate care periodically and reengaging with a mini patient round and review of systems can allow the medic to recognize changes in the patient's condition and reprioritize interventions.
  - Is the patient stable or unstable?
  - Is the patient sick or not sick?
  - Is the patient getting better or getting worse?
  - How is this assessment different from the last assessment?
- Obtain and interpret lab studies. When available, use labs to augment trends and physical exam findings to confirm or rule out probable diagnoses. Even if the local caregiver does not have the requisite knowledge to interpret the lab values in the clinical context, they can be obtained from telemedical consultation. Lab results may also serve as triggers to act or as measures of effectiveness of a previous intervention.
- Perform necessary surgical procedures. The decision to perform invasive and surgical interventions should consider both risks and benefits to the patient's overall outcome and not merely the immediate goal.

Telemedical Consultation Guide

To be used with Prolonged Field Care Card

1. Before calling, E-mail image of the casualty (wounds, environment, etc.), "capabilities" (back of page), & vital signs trends to the remote consultant.
2. If call not answered: a) call next number on PACE or call back in 5 – 10 min.
3. If unable to provide information due to operational security, state so.

P:
A:
C:
E:

This is _____ I am a (job/ position) _____

My best contact info is: _____

YOUR best contact info is (Consultant's number): _____Alternate e-mail: _____

**** PAUSE POINT to CONFIRM CONTACT INFO****

I have a _____ year–old _____(sex) _____ (active duty/foreign national/OGA,etc.), who has the following:

Mechanism of Injury or known diagnosis(es)

The injury/start of care occurred *hours ago*. Anticipated evacuation time is (*hours* from now):

Injuries/Problems/**S**ymptoms:

Treatments:

He/she is currently (circle) stable/ unstable, getting better/ getting worse/ getting worse rapidly

Known Medication Allergies/Past medical/Surgical history is:

I need help with (*be specific if possible, i.e. "I need help reading this ECG," or "I need help stabilizing this patient," etc.)*

Other Consultants have recommended:

**** PAUSE POINT for Remote Consultant to ask clarification questions ****

VITALS (*current* & *trend* as of): HR	BP	RR	SpO2	$EtCO_2$	Temp	
UOP(ml/hr) over	(# hours) Mental Status (GCS/ AVPU)					
EXAM: Neuro	Ext/ MSK					
Heart	Pulses					
Lungs	Skin/ Wounds					
Abd						
LABS: ABG:	Lactate:	Other:				

**** PAUSE POINT for Remote Consultant to ask clarification questions ****

Figure 2-4. Page 1 of a telemedical consult script to be used with the prolonged field care casualty card. Adapted from Vasios WN 3rd, Pamplin JC, Powell D, Loos PE, Riesberg JC, Keenan S. Teleconsultation in prolonged field care position paper. *J Spec Oper Med*. 2017;17(3):143.

Plans/Recommendations

PRIORITY	SYSTEM/PROBLEM	RECOMMENDATION
	Neuro or problem #1	
	CV or problem #2	
	Pulm or problem #3	
	GI or problem #4	
	Renal or problem #5	
	Endocrine or problem #6	
	MSK/ Wound or problem #7	
	Tubes, lines, drains or problem #8	
	Prophylaxis/prevention or prob#9	
	Other	

TO-DO/ FOLLOW-UP/TO-STOP	NOTES
1.	
2.	
3.	
4.	
5.	
6.	

**** PAUSE POINT, for Medic/Local Caregiver to ask clarification questions/READBACK****

Available "kit" (supplies, equipment, medications) !! IF POSSIBLE PHOTOGRAPH AND SEND VIA EMAIL BEFORE CALLING !!

Commo: Tempus i2i ID: _____ SAT#/Local Cell# _____

Other (FaceTime, VSee, Skype, WhatsApp ,etc.): _____

IV access: IV Central line IO (location) Other: _____

Monitor: Propaq Tempus Foley Graduated urinal PulseOx only Exam Only

Other: _____

IV Fluids: Plasma-Lyte LR Normal Saline 3% saline Other: _____

Colloids: Hetastarch Albumin Other: _____

Blood products: Whole blood PRBC Plasma FDP Platelets Other: _____

Medications: Antibiotics: name/route/dose _____

Morphine IV/ PO

Fentanyl IV/ PO (pop)

Midazolam

Other opioid (name/ IV/ PO): _____

Ketamine

Diazepam (IV/ PO)

TXA

Other(s): _____

Airway/Breathing: ETT Cric kit LMA BVM O2 Suction (type): _____ Ventilator(model): _____

Miscellaneous:

Figure 2-5. Page 2 of a telemedical consult script to be used with the prolonged field care casualty card.
Adapted from Vasios WN 3rd, Pamplin JC, Powell D, Loos PE, Riesberg JC, Keenan S. Teleconsultation in prolonged field care position paper. *J Spec Oper Med*. 2017;17(3):144.

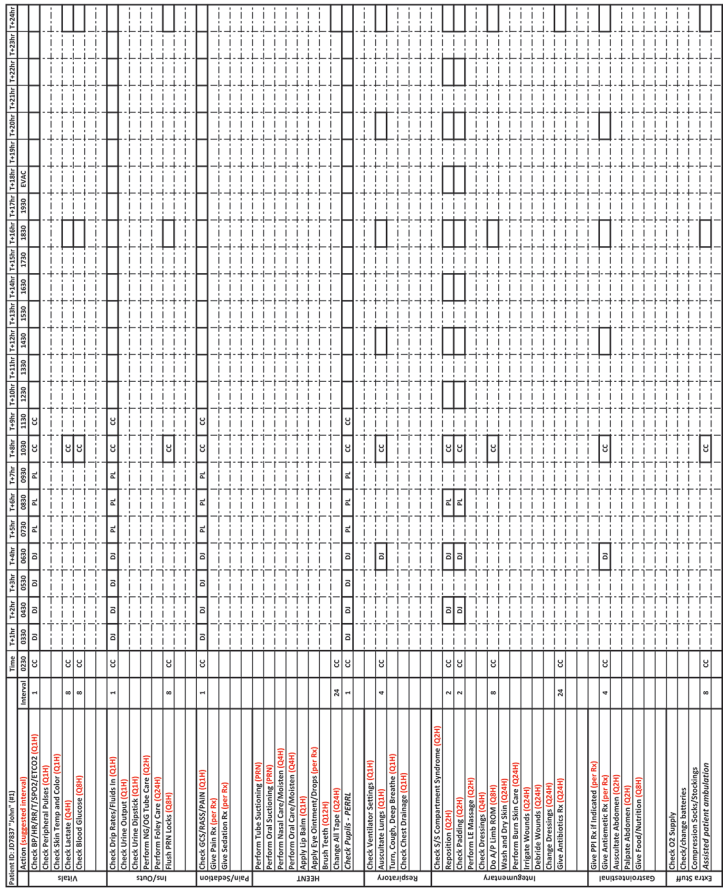


Figure 2-6. A 24-hour nursing care plan. Reproduced from Ostberg D, Loos P, Mann-Salinas E, et al. Joint trauma system clinical practice guideline: nursing intervention in prolonged field care (CPG ID: 70), appendix C. Joint Trauma System website. Published July 22, 2018. Accessed February 22, 2023. https://jts.health.mil/assets/docs/cpgs/Nursing_Intervention_Prolonged_Field_Care_22_Jul_2018_ID70.pdf

Preparation for Patient Transport

It should be anticipated and desired that the PC patient belongs somewhere else with a higher level of medical capability.

- The goal is to deliver the patient in the best physiological condition and with all pertinent information and administrative needs to continue care seamlessly through to the next role of care.
- The gathering of documentation, calculation of inter-transport pharmacological adjuncts, and completing other requirements for safe and successful travel begin when the patient arrives and continue until handoff.
- If the patient is evacuating out of the theater or off the continent, prepare ample drugs, fluids, and supplies. Prepare for contingencies in flight.
- A succinct handover relays all documentation, information on the immediate stability of the patient, treatments related to the illness or injury, next anticipated treatments, medical supplies and equipment, and any last-minute serious concerns to the next caregiver in the continuum of care.

Summary

PC challenges providers in many ways. The difficulties in a PC situation require individual and collective training to successfully overcome the inherent adversity and to optimize patient outcomes. An organized and proactive collective approach to managing PC will help practitioners provide the best possible care under the given circumstances, continuing until the patient can be evacuated to a higher role of care. Effective and efficient care relies on thorough patient documentation that includes a complete problem list, a tailored and updatable care plan, and continuous data trend analyses.

The most current TCCC and PC guidelines are available at www.deployedmedicine.com

Chapter 3

MANAGING TRAUMATIC BRAIN INJURY IN THE PROLONGED CARE SETTING

Joshua Luster, MD; Soukaina Noor, MD; and Adam M. Willis, MD, PhD

Introduction

With the expected changes in warfare, conflict with peer and near-peer adversaries requires planning for prolonged care (PC). Given the ubiquity of traumatic brain injury (TBI) throughout the history of combat, medics and tactical combat casualty care (TCCC) providers should be prepared to manage brain injuries in the PC setting. This chapter supplements the existing Joint Trauma System Clinical Practice Guidelines for Traumatic Brain Injury Management in Prolonged Field Care Setting.[1]

Key Principles

- Seek expert guidance to manage patients with TBI.
- Aim to minimize secondary brain injury.
- Keep good records. They are essential to identifying neurologic decline as soon as possible.
- Use consciousness level as an indicator of intracranial pressure.
- Become familiar with Joint Trauma System (JTS) overall goals for managing TBI in a PC setting (Exhibit 3-1).

Equipment and Supplies

Evaluating and managing TBI in a PC setting require sufficient equipment and supplies to stabilize the casualty and ultimately prepare them for transport to a higher role of care.

- ***Minimum:***
  - Equipment—
    - Vital sign trending chart.
    - Blood pressure cuff.
    - Stethoscope.
    - Wristwatch.

Exhibit 3-1. Joint Trauma System Overall Goals for Managing Traumatic Brain Injury in a Prolonged Care Setting

GOAL 1

Prevent secondary brain injury by ensuring adequate oxygenation and ventilation, avoiding hypotension, and detecting elevated ICPs.
Minimum: Periodic use of non-invasive vital sign monitors.
Best: Continuous vital sign monitors, Foley catheter, end-tidal CO_2 monitors, and hourly pupillometry.

GOAL 2

Maintain SBP >110 mm Hg.
Minimum: Stop bleeding and administer TXA.
Better: Repletion with 1 L 0.9% NS.
Best: Whole blood or blood products.

GOAL 3

Maintain a secure airway for GCS <8, facial trauma, or compromised airway.
Minimum: Nasopharyngeal airway or bag-valve-mask with PEEP valve.
Better: Cricothyroidotomy or supraglottic airway and sedation and oxygenation.
Best: Cricothyroidotomy or supraglottic airway and sedation and oxygenation with ABGs to track oxygenation.

GOAL 4

Prevent infections.
Minimum: Dress all wounds.
Better: Provide Ertapenem 1 g IV/IO q24h and moxifloxacin 400 mg PO q24h.
Best: Provide antibiotics with strong CNS penetration; ceftriaxone 2 g IV/IO q24h or cefazolin 2 g IV/IO q8h for 5 d plus metronidazole 500 mg IV/IO q8h if wounds have organic debris.

(**Exhibit 3-1** *Continues*)

Exhibit 3-1 *Continued*

GOAL 5

Identify and manage seizures.
Minimum: Midazolam 5 mg IV/IO/IM q5min until seizures stop.
Best: Levetiracetam 2000 mg IV/IO loading dose over 15 min with 500 mg q12h versus phenytoin 1.5 g IV/IO load over 30 min and 100 mg IV/IO q8h versus phenobarbital 1.5 g IV/IO load over 15 min and 100 mg IV/IO daily.

GOAL 6

Maintain core temperature between 96-99.5 °F.
Minimum: Remove patient from heat or sun, remove clothing, and use surface cooling measures.
Better: Apply cold packs to the axilla, posterior neck, and groin.
Best: Acetaminophen 650 mg PO/PR q4h for temperatures over 99.5° and cold saline IV boluses.

GOAL 7

Avoid hyponatremia, with a goal of mild hypernatremia 145-160 mmol/L.
Minimum: Avoid free water of hypotonic fluids.
Best: Monitor serum sodium by blood samples; if stable q6h but if unstable, then q3h.

GOAL 8

Avoid hypo/hyperglycemia, with a target BG of 100-180 mg/dL.
Minimum: Monitor for signs and symptoms of hypoglycemia and allow the patient to eat if able.
Best: Check BG q6h with a glucometer, and if <100 mg/dL, give 50 mL D50 IV/IO or 5 tsp sugar versus 4 tsp honey PO/NG.

GOAL 9

Transport TBI patients by ground or air to high levels of care.
Minimum: dose sedative/analgesics/osmotic therapy/benzodiazepines before transport if possible.
Best: Provide a detailed brief to the transport team and highlight neurologic deficits and treatments that may be required during transport.

(**Exhibit 3-1** *Continues*)

Exhibit 3-1 *Continued*

Abbreviations: ABG, arterial blood gas; BG, blood glucose; CNS, central nervous system; GCS, Glasgow Coma Scale; ICP, intracranial pressure; IM, intramuscular; IO, intraosseous; IV, intravenous; NG, nasogastric; NS, normal saline; PEEP, positive end-expiratory pressure; PO, per os; PR, per rectum; SBP, systolic blood pressure; TBI, traumatic brain injury; TXA, tranexamic acid.
Compiled from Van Wyck D, Loos P, Friedline N, et al. Traumatic brain injury management in prolonged field care (CPG ID: 63). Joint Trauma System website. Published December 6, 2017. Accessed December 16, 2022. https://jts.health.mil/assets/docs/cpgs/Traumatic_Brain_Injury_PFC_06_Dec_2017_ID63.pdf

        - Pulse oximeter.
        - Capnometer.
        - Cricothyroidotomy kit.
        - Bag-valve-mask with positive end-expiratory pressure (PEEP) valve.
        - Nasopharyngeal airway.
        - Disposable thermometer.
        - Plastic bottle to measure urine.
    - Medications and fluids—
        - Ketamine.
        - Midazolam.
        - Lorazepam.
        - Acetaminophen.
        - Ceftriaxone.
        - 3% hypertonic saline, 30 mL.
- ***Better:***
    - Equipment—
        - Portable vital sign monitor.
        - Capnometer.
        - Cricothyroidotomy kit and/or endotracheal tube (ETT).
        - Laryngoscope/glidescope and/or laryngeal mask airway.
        - Cold packs or ice packs.
        - Graduated cylinder to measure urine.
        - Oxygen concentrator.
    - Medications and fluids—
        - Intravenous (IV) hydromorphone.

    - IV fentanyl.
    - Midazolam.
    - 30 mL of 23.4% hypertonic saline.
    - Propofol.
- ***Best:***
    - Equipment—
        - Portable monitor providing continuous vital signs display with capnography.
        - Cricothyroidotomy kit, and/or ETT plus laryngoscope/glidescope.
        - Portable point-of-care testing device, such as an iSTAT (Abbott Point of Care), for arterial blood gas samples and electrolyte monitoring.
        - Blood glucose monitor.
        - Foley catheter kit.
        - Supplemental oxygen or oxygen concentrator.
    - Medications and fluids—
        - Fresh whole blood drawing supplies or stored blood products.
        - 3% hypertonic saline.
        - Mannitol.
        - Ceftriaxone.
        - Metronidazole.
        - Levetiracetam or phenytoin.
        - Acetaminophen.
        - Dextrose 50% in water.
- ***Bonus:***
    - Portable ultrasound.
    - Quantitative pupilometer.
    - Tranexamic acid (TXA).

Neurologic Injury

There are two key classes of neurologic injury:

- Primary—the initial, irreversible injury that followed trauma.
- Secondary—progression of the initial injury or additional tissue at risk. This is due to impaired delivery and oxygen use at the brain tissue level, secondary to the physiologic changes that occur following trauma.

Key Clinical Features

- Elevated intracranial pressure (signs to worry about):
  - Pupillary dilatation.
  - Motor posturing (extensor or flexor) (Figure 3-1).
  - Glasgow Coma Scale (GCS) <8.
- Increasing intracranial pressure (signs to watch for):
  - Decrease in GCS.
  - Nausea and vomiting.
  - Drowsiness.
  - Worsening headache.
  - Loss of cranial nerve reflexes.
- Herniation (signs to watch for):
  - Acute hypertension.

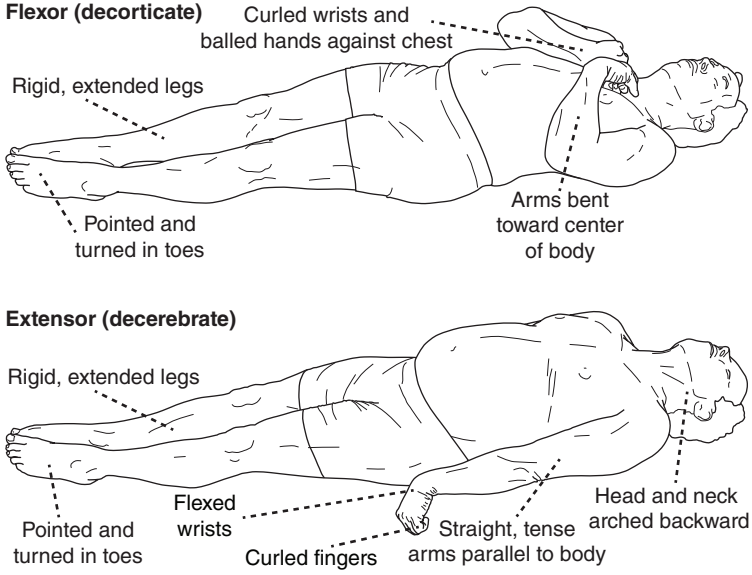


Figure 3-1. Abnormal motor posturing. In flexor (decorticate) posturing, the patient's elbows, wrists, and fingers are flexed. The patient's legs are extended and internally rotated. In extensor (decerebrate) posturing, the patient's head and next are arched backward. The patient's arms, legs, and toes are extended. Illustration by Borden Institute.

  - Acute loss in mental status.
  - "Blown" pupil(s) (enlarged and nonreactive).
  - Motor posturing (extensor or flexor).
  - Ataxic breathing or apnea.
- Seizure clinical findings (signs to watch for):
  - Tonic eye deviation.
  - Rhythmic motion (1-4 Hz) with eyes, face, and arms.
  - Cyclic agitation or somnolence.

Minimizing Secondary Injury

In addition to other PC guidelines, the management of brain injuries has modified parameters to maximize oxygen delivery to brain tissue. These include the following[1,2]:

- Keep the patient's systolic blood pressure above 110 mm Hg to avoid hypotension.
- Keep the patient's Spo_2 >90 or (>93% if intubated) to prevent hypoxia.
- Keep the patient's head 30° to 60° from horizontal.

Review of a Practical Prolonged Care Neurologic Examination

The neurologic exam is the best assessment of intracranial pathology. However, not all components of the full neurologic examination provide high-yield information in triaging and managing an acute TBI in the PC setting. Given the lack of other diagnostics in the PC setting, systematically tracking this exam is ***critical*** in identifying which patients require additional management to minimize secondary injury. Although reduced resources will limit the extent of the neurologic examinations, conduct some regular examinations and record results to look for a neurologic decline. Exhibits 3-2 and 3-3 provide a rapid and high-yield neurologic exam for both awake patients and patients in a coma.

Note: Avoid confounding the exam from oversedation or analgesia as much as clinically possible.

The level of consciousness of your patient is a fantastic surrogate for intracranial pressure.[3] Thus, if a patient is alert, awake, and oriented, then the patient does not have significantly elevated

intracranial pressure. It is never normal to have to stimulate a patient to stay awake or follow commands (unless sedated). Follow such patients very closely. Progression of intracranial injury should be the top concern in any patient who requires consistent stimulation to participate in an exam or manifests with a decline in their baseline level of consciousness or loss of orientation to person, place, or time. However, an alert patient with a head injury still requires monitoring. Some intracranial injuries can progress over time and manifest as early changes on an exam before intracranial pressure increases to dangerous levels.

Other exam findings may provide valuable information about the localization, extent, and progression of mass lesions in intracranial injury. These findings include:

- Focal weakness.
- Changes to orientation (person, place, time).
- Difficulty in naming common objects or following simple commands.
- Inattention to their left side.
- Loss of visual fields on either side.

Some of these findings may be subtle, such as:

- Presence of pronator drift.
- Upper extremity extensors (triceps, finger extension).
- Lower extremity ankle dorsiflexion.

Exhibit 3-2. Instructions for Conducting a Rapid Coma Exam

STEPS

1. Observe to determine if there are any spontaneous movements (rhythmic or purposeful), or eyes open.
2. Yell the patient's name and ask them to perform a:
   a. Midline command ("open eyes" and "stick out tongue").
   b. Limb command ("show me two fingers" or "give me a thumbs up").

(**Exhibit 3-2** *Continues*)

Exhibit 3-2 *Continued*

3. If the patient is not following commands:
   a. Choose a side (left or right) and place the patient's contralateral arm (right or left) flexed and near (but not crossing the midline) while holding down their ipsilateral arm (left or right).
   b. Firmly squeeze the patient's trapezius or pectoral muscle belly and watch for crossing of their contralateral arm across the midline toward where you are pinching.
   c. If the patient's arm crosses the midline, then the patient is localizing (M5).
   d. If the patient does not cross the midline with their hand, then provide nail bed pressure on their ipsilateral (left or right) arm. If the patient is purposeful (ie, different movement for different stimuli), then it is a withdrawal (M4).
   e. If the patient's arm flexes or extends similarly for different stimuli (nailbed versus trapezius pinch), then the patient is either decorticate (M3) or decerebrate (M2), respectively.
   f. Repeat step 3 on other side.
   g. Apply nailbed pressure to a lower extremity.
   h. If there is motion, repeat a pinch on the patient's inner thigh. If there is ankle dorsiflexion, knee flexion, and hip flexion to both stimuli, then the patient is "triple-flexing." If there is a different response to both stimuli, then the patient is withdrawing.
4. Check the patient's pupil reactivity and symmetry on both sides and look for any spontaneous motion, tonic eye deviation, or rhythmic motion.
5. Open the patient's eyes and apply 1 drop of isotonic fluid in each. If there is a blink response, then the patient is corneal intact.
6. Look at facial symmetry and rhythmic motion.
7. Check gag or cough.
8. Record the exam findings.

Example Report to a Specialist: "GCS 5T (E1,V1T, M3), flexural posturing right upper extremity, extends left upper extremity, triple flexion bilateral lowers. Pupils 3 mm, reactive, midposition. Corneal intact on right, absent on left, intact cough."

Exhibit 3-3. Instructions for Conducting a Rapid Neurologic Exam.

STEPS

1. Check alertness: "What is today's date, month, year," and "what happened today."
2. Check visual fields:
   a. Cover the patient's right eye with your left hand.
   b. Ask the patient to look at your nose, then quickly bring your right hand toward the patient's left eye, from the left (as if to poke their eye).
   c. If the patient blinks, then the blink reflex is intact.
   d. Repeat on the patient's other side.
3. Pupillary exam and extra-ocular movements: check for limited range of eye motion or any reports of double vision.
4. Check pronator drift bilaterally:
   a. Ask the patient to close their eyes and hold up "two cups of soup" (both arms out, palms up).
   b. Watch for 5 seconds for any palm pronation (rotation) and record if present.
5. Check strength of biceps, triceps, finger extensors, and hip flexion and dorsiflexion. Check both sides simultaneously to detect subtle weakness.
6. Perform a pin prick on all limbs. Only look for gross absence or differences in response.
7. Record exam.

Example Report to a Specialist: GCS 14 (E3, V5, M6), oriented to person, place, date, and situation. Visual fields intact, pupils 3 mm, equal and reactive with full extraocular motion. Pronator drift on right upper extremity and 4/5 strength of right triceps, otherwise 5/5 strength throughout. Pinprick intact on all extremities.

Perform a brief sensory exam (unless there is concern for a spinal cord lesion), which only includes checking the presence of sharp sensations in all extremities. Bilateral loss of sensory and motor functions (both legs and/or both arms) with loss of muscle tone and reflexes in arms or legs in an awake patient likely indicates a spinal cord lesion. Crossed findings, such as weakness on one

side and loss of pinprick sensitivity on the other side, also indicate a spinal cord lesion.[4]

For any patient not following commands, at a ***minimum***, all patients should have regular (every 1-2 h) GCS with a pupillary exam (assessing reactivity to a penlight). See Exhibit 3-2 for a more comprehensive (yet still rapid) coma exam. Additionally, because motor scores are recorded from the highest value (eg, a left upper extremity withdraw and right extensor posturing is scored as an M4), keep motor scores for both sides. Each patient's score would include the following: Eyes (__/4), Verbal (__/5), Motor (L/6, R/6), L/R pupil reactive.[5] For patients able to follow commands, perform a more complete (yet still succinct) neurologic examination (see Exhibit 3-3) that aims to detect acute worsening of either brain or spinal cord injuries.

Patterns of Worsening

Management of TBI is complex. It is imperative to seek expert consultation ***as soon as possible*** for guidance in management. However, by being aware of the patterns of injury and progression, PC providers will be more likely to detect changes and escalate care appropriately.

Expansion of Intracranial Mass Lesion

Moderate and severe head trauma can lead to intracranial bleeding or brain contusions. These lesions can expand into neighboring healthy brain tissue. In the PC setting, your job is to both minimize the expansion of existing mass lesions AND detect new expansion. Minimize risk of expansion by ensuring a balanced resuscitation and avoidance of coagulopathy and hypothermia via JTS guidelines.

Note: Tranexamic acid (TXA) is safe in TBI.[6]

Detecting an expansion is necessary to inform which patients need urgent neurosurgical intervention. The ***best*** way to detect an expansion is to suspect an underlying mass lesion and know the clinical patterns of worsening (Exhibit 3-4). The clinical exam can often detect a mass lesion and inform its location. The basic

Exhibit 3-4. Patterns of Cortical Injury That Identify a Worsening Condition in a Patient With Brain Injury

Left Cortex

- Difficulty naming, slowed speaking, poor command following.
- Right-sided weakness.
- Right visual field loss.
- Eyes not crossing the midline to look right.

Right Cortex

- Left-sided weakness.
- Left-sided neglect (not paying attention to left).
- Left visual field loss.
- Eyes not crossing the midline to look left.

rule is ***findings are crossed***. For example, a left pronator drift suggests a mass lesion on the right brain. The expansion of this lesion would additionally affect the right cortex and thus show more right cortical signs: left-sided weakness, inability for eyes to cross the midline, and left visual field loss. These are usually the first clinical signs to appear if the patient worsens. For an initially awake patient, these clinical signs can detect mass lesion progression sooner than changes in GCS. By detecting these signs early, the PC treatment team gets more time to obtain expert consultation, plan for evacuation, or become more aggressive in resuscitation.

Seizures

Seizures are common following TBI. Detection of seizures in the PC setting can be challenging—not all shaking is seizure activity (eg, shivering). Following any seizure or convulsion event, consult with experts once the patient is clinically stable.

The key attributes of a seizure are rhythmicity and frequency of 2 to 4 convulsions or movements per second. Generalized motor seizures are the easiest to detect—bilateral rhythmic contractions with loss of consciousness. Treat seizures in accordance with their duration or repetition:

- A short seizure (1-2 min) with a return to baseline following a TBI is concerning and warrants an increase in prophylaxis.

- Abort longer duration seizures (>3 min) with short-acting benzodiazepines (5 mg midazolam intramuscular [IM] or 4 mg lorazepam IV)[7] and, if available, either—
  - a load of antiseizure medicines (up to 60 mg/kg levetiracetam[8]) or
  - an increase in seizure prophylaxis dosing (1000 mg bid levetiracetam).
- For any prolonged seizures (>5 min), multiple repeated seizures (<5 min), or any time a patient does not return to previous baseline following a seizure (within 10 min)—
  - secure the airway and
  - use general anesthetics such as propofol or ketamine to abort presumed status epilepticus.

Patients may also have seizures without clear clinical convulsions. Subtle findings of unilateral limb or face twitching with rhythmicity of 2 to 4 Hz[9] and rhythmic or tonic eye deviations can be clues that a nonresponsive patient is having a seizure. Fluctuations in exams (alternating periods of unresponsiveness to agitation) not correlated with pharmacologic sedation may also indicate seizure activity. In the PC setting, unless the patient is awake and alert during these focal motor seizures, ***treat subtle seizures as generalized seizures*** and abort them with benzodiazepines, antiseizure medications, and general anesthetics, as needed. If using general anesthetics to stop seizures, monitor blood pressure and maintain systolic blood pressure (SBP) or mean arterial pressure (MAP) goals. Even if the patient is fully resuscitated, it may be necessary to use vasopressors.

Note: Opioid sedatives and neuromuscular paralysis do not stop seizures and thus should not be first-line treatments. Avoid continuous neuromuscular blockade as it masks additional seizures from clinical detection. If there is a concern for seizures, seek expert consultation.

Global Intracranial Pressure Crisis

In addition to focal mass lesions, TBI can manifest in global elevations in intracranial pressure. Treat any patient with altered mental status following TBI as having increased intracranial

pressure until proven otherwise. Point-of-care ultrasound, both optic nerve sheath diameter (ONSD)[1] (Exhibit 3-5) and resistivity index / pulsatility index[10–12] (Exhibit 3-6) can identify trends of intracranial pressure and provide helpful information for remote consultants. Furthermore, quantitative pupillometry is a powerful and reliable tool to follow exams and predict intracranial pressure (ICP) crisis.[13–15] On examination, patients with the following signs are more likely to have elevated ICP:

- Unreactive pupillary dilation.
- Motor posturing (see Figure 3-1).
- GCS <8.

Pressure within the human head is grossly a function of the volume of the intracranial contents—brain, venous blood, arterial blood, and cerebrospinal fluid. Following head trauma, small changes in the volume of any one of these compartments yield significant changes in pressure. To maximize cerebral perfusion in patients with increased ICP, focus medical therapy on optimizing the volumes of brain, venous blood, arterial blood, and cerebrospinal fluid.

Decrease the volume of brain tissue by maintaining a high intra-arterial osmotic load ("drying" the brain out). Use the following guidance for a patient with unknown ICP who remains in a coma[1,2]:

- Consider setting 155 mEq/L as a target serum sodium level (typically, patients tolerate serum sodium levels of up to 155 mEq/L).
- Administer 250 mL 3% NS boluses every 3 hours and monitor serum levels.

Because of the sensitivity of ICP to serum osmolality, ***avoid hypotonic fluids***.

Note: NS is the resuscitation fluid of choice for brain injuries.[16]

Maintaining adequate intravascular volume when using mannitol for osmotic therapy is more challenging given its potent diuretic effect. If using mannitol:

- Insert a Foley catheter.
- Monitor diuresis.
- Administer additional IV fluids to maintain euvolemia.

Because of this diuretic effect, using mannitol for prolonged management of TBI in PC is not ideal.

Venous congestion can also increase ICP secondary to hindering drainage of venous blood from the head. A key strategy to maximize venous drainage is to minimize intrathoracic pressure while maintaining Spo_2 93% to 95% (if ventilated, minimize positive end-expiratory pressure [5-15 cm H_2O usually is tolerated]). Another strategy is to sit the patient up at a hip angle of 30° to 60° for optimal blood flow and ICP.[1] Keeping the patient's head in mid-position and avoiding tight cervical collars (that visibly compress the anterior neck) will also reduce venous congestion and ICP.

Arterial blood volume also affects intracranial volume, which can alter ICP. Hyperventilation decreases arteriole blood volume and will temporarily reduce ICP. However, the risk of prolonged

Exhibit 3-5. Safe and Rapid Optic Nerve Sheath Diameter (ONSD) Ultrasonographic Assessment for Elevated Intracranial Pressure in Unconscious Patients With Head Injury

Steps to assess optic nerve sheath diameter:

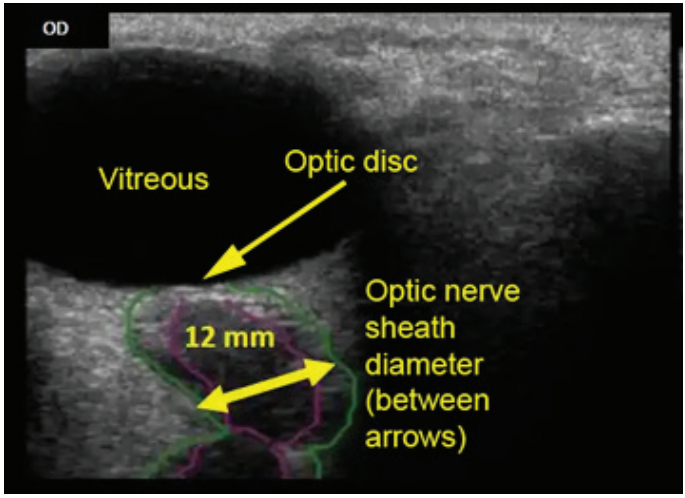
1. Ensure there is no eye injury and the eyelids are closed.
2. Ensure the head and neck are in a midline position.
3. Ideally, place a thin and transparent film over the eye.
4. Apply ultrasound gel.
5. Place the 10-5 MHz linear probe on the eyelid horizontally with minimal pressure.
6. Find the optic nerve and nerve sheath and freeze the screen.
7. Measure 3 mm from the optic disc and obtain a measurement perpendicular to the optic nerve.
8. Repeat in the other eye.
9. Continue to monitor and measure ONSDs hourly.

(**Exhibit 3-5** *Continues*)

Exhibit 3-5 *Continued*

Factors to consider:

- The optic nerve sheath communicates with the subarachnoid space.
- Normal ONSD is 4.1-5.9 mm.
- ONSDs over 5.2 mm should raise concern for elevated ICP in TBI patients.



Abbreviations: ICP, intracranial pressure; ONSD, optic nerve sheath diameter; TBI, traumatic brain injury.
Purple: optic nerve; green: optic nerve sheath.
Image adapted from National Aeronautics and Space Administration Evidence Report VIIP, Figure 6. https://humanresearchroadmap.nasa.gov/evidence/reports/VIIP.pdf

hyperventilation is rebound ICP at normal P_{CO_2} levels and reduced blood flow to the brain. Generally, use hyperventilation only as a bridge to other ICP-reducing therapies (osmotic therapy, additional sedation, emergent surgery, etc). Targeting a CO_2 of 35 to 40 mm Hg is reasonable.

Arterial blood volume decreases during sedation. Use the following guidelines for sedation:

- Maintain sedation to keep a Richmond Agitation Sedation Scale (RASS) of –1 to –2. This should further reduce ICP.
- If the patient's exam is worsening, increase sedation to RASS of –4 (Table 3-1, tiers 1-3).

Note: Make your anesthesia choice in conjunction with expert consultation.

Ketamine effectively reduces agitation and the risk of hypotension, which may be optimal in the PC setting. Relative to ketamine, propofol has more profound reductions in cerebral metabolic demand and blood flow but is much more likely to require vasopressors to maintain cerebral perfusion. Propofol is not preferred in the PC setting.

Note: Change MAP goals only in coordination with critical care or neurosurgical expertise, as it is possible that elevating MAP would further elevate intracranial pressure as well.

Episodes of agitation also increase ICP; therefore, it may be necessary to discontinue neurologic examination beyond pupils and cranial nerve examinations and maintain a lower RASS without sedation breaks if agitation does not quickly resolve after each examination. Increased ICP also can occur if portions of the brain are not receiving enough blood flow. Thus, if there is a concern for increased ICP, consider increasing MAP goals to 80 to 90 mm Hg via vasopressors.[17]

The signs of elevated intracranial pressure in comatose patients can be subtle, but during acute ICP crisis, Cushing's triad can occur:

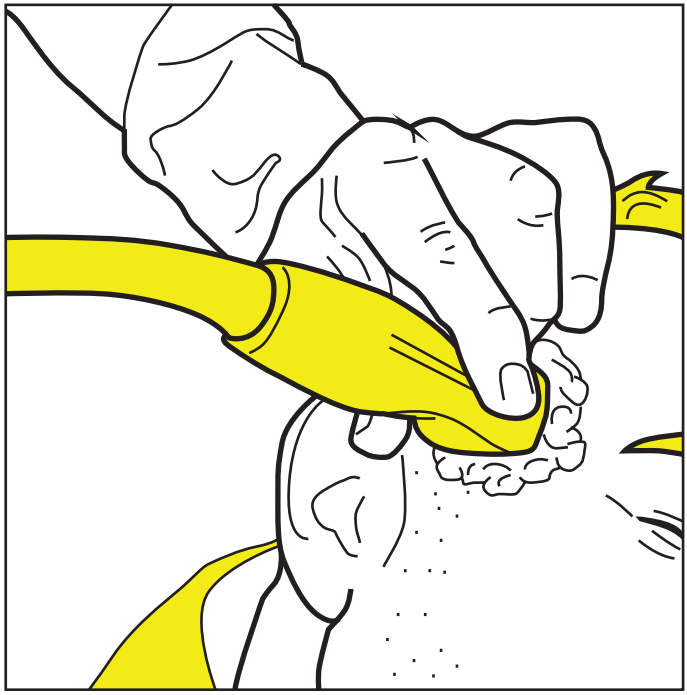
- Hypertension (or widened pulse pressure).
- Bradycardia.
- Irregular breathing.

Exhibit 3-6. Monitoring Intracranial Pressure Using Resistivity Index (RI) and Pulsatility Index (PI) Calculations

Insonate the middle cerebral artery (it will be flowing toward you) and measure velocity through the cardiac cycle using hand-held ultrasound in Doppler mode.

Measure middle cerebral artery velocity:

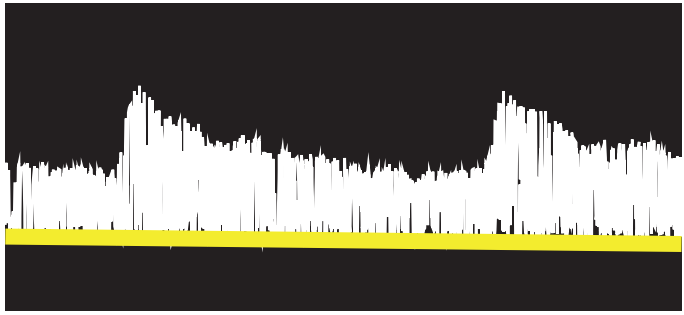
1. Use a phased array probe at maximum power, and with maximum insonation depth of 6 cm.
2. Place the transcranial Doppler (TCD) probe on the temporalis, with the indicator pointed toward eyebrows.



(**Exhibit 3-6** *Continues*)

Exhibit 3-6 *Continued*

3. Use color flow to identify pulsatile flow toward the probe (usually 3-4 cm of depth).



4. Measure the velocity of pulsatile flow via Doppler mode.
5. Record peak systolic velocity (PSV), end diastolic velocity (EDV), and mean flow velocity (MFV) (if available).
6. Calculate RI using PSV and EDV. PI is more accurate than RI but requires a calculation by the ultrasound device of the mean flow velocity (MFV) or the time-averaged flow velocity.

Measurement	Formula	Cutoff[a]
Resistivity index	(PSV-EDV) ÷ PSV	>0.57
Pulsatility index	(PSV-EDV) ÷ MFV	>2.1

[a] Threshold between normal and abnormal, indicating risk of elevated intracranial pressure.

7. Monitor hourly.

Note: when using TCDs, PI, and RI—
- It is best to follow trends.
- Higher RI and PI correlate with higher intracranial pressure.
- Decreased P_{ACO_2} can influence cerebral blood flow.
- Decreases in mean arterial pressure can raise the PI.

Illustration by Borden Institute.

Also, if one or both pupils "blow," the patient is undergoing acute herniation. Perform aggressive medical management—PC Tier 3 (see Table 3-1).

Herniation

The brain comprises multiple compartments separated by rigid structures (tentorium). The major intracranial arteries are next to these rigid structures. If the pressure in one compartment exceeds the pressure of the adjacent compartments, brain tissue can push out of its compartment. In addition to damaging the herniating tissue, a herniating brain may compress the adjacent artery, which can lead to strokes.

Note: A herniation syndrome is an emergency that requires immediate medical intervention, usually followed by surgical decompression.

Immediate medical intervention for herniation includes the following[2,17]:

- A rapid bolus of 250 mL 3% NS (vs 30 mL of 23.4%).
- 1 g/kg of mannitol.
- Briefly hyperventilating patient to $Etco_2$ of 25.

Rapid evacuation for surgical intervention, which may not be possible in a PC setting, will likely be necessary to prevent irreversible neurologic injury or progression to brain death. However, there are reports of medical reversal of herniation with meaningful neurologic recovery.[18,19]

Clinically, three herniation syndromes are the most common:

- Uncal herniation—
  - Initially presents with the "blown" pupil on the same side as the mass lesion.
  - Is often followed by posturing (extensor or flexor) or hemiparesis (on either side).
  - Irregular breathing usually occurs.
- Subfalcine herniation—
  - Is more difficult to detect than uncal herniation.
  - Look for new onset leg weakness associated with headache.
  - Sleepiness could occur.

Table 3-1. Intervention Tiers for Prolonged Care to Guide Treatment of Patients With Brain Injury

Tier 0 (start here)	Tier 1 (not following commands)	Tier 2 (worsening baseline coma exam)	Tier 3 (herniation)
• Optimize ABCs • Minimize noxious stimuli • RASS –1 to –2 • Hourly brief neuro checks • Neck midline • HOB 30° • NS or blood product resuscitation • Na >135 mEq/L • Keep euvolemic (avoid hypovolemia) • SBP >110 mm Hg • $Etco_2$ 35-40 mm Hg • normothermia	• Tier 0+ • Goal Na >140-145 mEq/L: 3% at 75-150 mL/h (250 mL q3h) • Consult with specialist after initiation	• Tier 1+ • Consult with specialist before initiating • Increase goal Na >150-155 mEq/L • Sedation RASS - 4 ○ Propofol 50-70 μg/kg/min ○ Maintain MAPs >80-90 mm Hg via phenylephrine (vs norepinephrine)	• Tier 2+ • Treat immediately and call a specialist after initiation • 30 mL of 23.4% NS over 5 min and/or mannitol 1 g/kg bolus • Hyperventilate Pco_2 (25-34 mm Hg) <2 h • Match UOP with NS every 1-2 h

Abbreviations: ABCs, airway, breathing, circulation; HOB, head of bed; MAP, mean arterial pressure; NS, normal saline, RASS, Richmond Agitation Sedation Scale; SBP, systolic blood pressure; UOP, urinary output.

- Cerebellar herniation—
  - Often presents rapidly with loss of consciousness.
  - Watch for disruption in cranial nerves.
    - Loss of corneal reflex.
    - Gag or cough.
    - Inability to move eyes in all directions.
    - Irregular breathing.
  - Circulatory collapse and cardiac death often occur.

Escalation of Treatment

Use Tier 0 to 3 guidance (see Table 3-1) for escalating management of worsening ICP in the PC setting.

- Employ PC Tier 0 in almost all brain-injured patients.
- If the patient is not following commands, proceed to Tier 1.
- If the exam worsens or there are signs of worsening (in consultation with a specialist), consider moving to Tier 2.
- Employ PC Tier 3 immediately if you see signs of herniation or Cushing's triad. Tier 3 should include the following:
  - Rapid osmotic therapy, with a 250 mL bolus of 3% NS or 30 mL of 23.4% saline if available.
  - A bolus of mannitol 1 g/kg.

Note: If using mannitol, remember to insert a Foley catheter and monitor urine output. Keep the patient euvolemic with IV fluids.

- Following Tier 3, call specialists for further guidance.

Summary

Management of TBI in the PC setting is challenging. Communication with remote experts is critical. By being familiar with the likely complications of brain injury (seizures, expanding mass lesion, global ICP crisis, or herniation), you will more likely detect early signs of decline to triage, evacuate, and communicate with experts appropriately. Practicing the rapid coma exam and rapid neuro exam will prepare you to identify abnormal findings quickly. Practicing point-of-care ultrasound will also improve your speed and accuracy of measuring optic nerve sheath diameter and resistivity index to monitor ICP noninvasively.

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Chapter 4

CHEMICAL, BIOLOGICAL, AND RADIOLOGICAL CASUALTY MANAGEMENT

Joseph K. Maddry, MD, and Patrick C. Ng, MD

Introduction

Diagnosing and managing chemical, biological, radiological, and nuclear weapons casualties present unique challenges in the prolonged care (PC) environment. Focus medical efforts on using signs and symptoms to identify the exposure, decontaminate as indicated, provide supportive care, administer antidotes and antibiotics if appropriate and available, and prepare the casualty for evacuation to a higher level of care (versus return to duty). Furthermore, it is crucial to prevent secondary exposures using proper equipment and guidance from a well-reasoned disaster management plan.

Key Principles

- Don personal protective equipment as necessary to prevent exposure.
- Decontaminate casualties exposed to toxic liquids, vapors, powders, or radioactive particles when in an area free from further exposure. Decontaminate by removing clothing and washing thoroughly with soap and water as available.
- Decontamination is unnecessary if exposure is limited to gas or gamma radiation.
- Handle and dispose of contaminated materials (eg, clothing, equipment, and gear) systematically via a clear, practical action plan.
- Identify the exposure using signs and symptoms and available testing equipment.
- Provide airway management, supportive care, antidotes, and antibiotics as indicated.

Chemical Weapons Exposure

The primary chemical weapons of concern are organophosphates, respiratory agents, vesicants, and cyanide (Table 4-1).

Organophosphates

Organophosphates (OPs), commonly called nerve agents, inhibit the enzyme acetylcholinesterase, resulting in excessive stimulation of the post-synaptic cholinergic and nicotinic receptors.

Signs and Symptoms

The excessive stimulation of cholinergic receptors results in a toxidrome of symptoms, which can be memorized using the acronym **SLUDGE and the killer B's**:

- **S**alivation.
- **L**acrimation.
- **U**rination.
- **D**efecation.
- Increased **G**astric motility.
- **E**mesis.
- **B**radycardia.
- **B**ronchospasm.
- **B**ronchorrhea.
- **S**eizure.

Symptoms resulting from the excessive stimulation of nicotinic receptors include muscle fasciculation, weakness, paralysis, and seizures. Casualties may die from respiratory failure caused by excessive bronchorrhea and respiratory muscle fatigue.

Management

Decontamination.

- For casualties exposed to vapor via inhalation, decontaminate by moving them to fresh air.
- For casualties with vapor or liquid skin exposure, apply one of these two decontamination options.
  - Use the charcoal skin-decontamination kit.
  - Irrigate copiously with soap and water.

Table 4-1. Chemical Weapons

Class	Specific agents	Signs and symptoms	PC management[a]
Nerve agents	Sarin, Soman, Tabun, VX	Salivation, lacrimation, urinary incontinence, diarrhea, vomiting, bronchorrhea, bradycardia, bronchospasm, seizures	Atropine, pralidoxime, benzodiazepines, respiratory support
Respiratory agents	Ammonia, chlorine, phosgene, nitric oxide	Fever, cough, SOB, arthralgias, pulmonary edema	Supportive care, ventilatory management if necessary
Vesicants	Mustards, lewisite	Eye irritation, chemical conjunctivitis, skin erythema, vesicles, bullae, skin necrosis, hoarseness, cough, SOB	Supportive care, ventilatory management if necessary
Cyanide	Cyanide gas, cyanide salts	Cough, SOB, headache, confusion, seizures, coma	Hydroxocobalamin

Abbreviations: PC,prolonged care; SOB, shortness of breath.
[a] Decontaminate as indicated and prevent secondary exposures with the proper use of personal protective equipment.

Note: OPs are among the few chemical hazards that can cause fatal toxicity via skin absorption.

Treatment. Treat casualties with intramuscular (IM) or intravenous (IV) atropine. Atropine blocks the post-synaptic acetylcholine receptors, decreasing the SLUDGE and the killer B's symptoms. However, it does not affect the nicotinic receptors. Dermal exposure can result in toxicity that is more significant for a prolonged duration. In a PC environment, the medic may deplete their atropine supply and require emergency resupply. Administer atropine as follows:

- Doses for inhalational exposure typically range from 1 to 6 mg IV or IM. Each autoinjector contains 2 mg of atropine.
- For mild symptoms, administer 2 mg of atropine via an IM autoinjector. Repeat injections every 5 to 10 minutes for three doses (total), as needed.
- For severe symptoms, immediately give three doses of the 2 mg autoinjector. In the PC environment, repeat the 2 mg dose as needed for the recurrence of symptoms.
- An alternative treatment for severe symptoms is a single 2 to 6 mg IV dose, followed by a continuous infusion of 1 to 30 mg/kg/h. Titrate as necessary to decrease oral and pulmonary secretions while ensuring adequate oxygenation and ventilation.

Note: Tachycardia resulting from atropine is not a contraindication to further dosing.

Pralidoxime and other oximes chemically remove the OP from acetylcholinesterase. Some OPs (particularly chemical warfare agents) undergo "aging," which is the development of a permanent covalent bond between the OP and acetylcholine. Therefore, for pralidoxime to have an effect, administer it before OP aging. Some OPs, such as soman, can age within minutes; consider oximes early in the clinical assessment. Administer pralidoxime as follows:

- For mild symptoms, administer pralidoxime as an IM autoinjector dose of 600 mg. Repeat injections every 15 minutes for three doses (total), as needed.
- For severe symptoms, immediately give three doses of the 600 mg autoinjector. In the PC environment repeat the 600 mg dose as necessary to treat a recurrence of symptoms.
- An alternative treatment for severe symptoms is a single 1000 to 2000 mg IV dose followed by a continuous infusion of 8 to 500 mg/kg/h, titrated to control symptoms.

For respiratory depression resulting from excessive stimulation of the nicotinic muscle receptors that is failing to respond to pralidoxime, treat as follows:

- The best choice is endotracheal intubation with mechanical ventilation.
- Alternatively, conduct manual ventilation using the bag-valve-mask if adequate airway management equipment and skills are not available.

Benzodiazepines are the treatment of choice for OP-induced seizures. Use the following guidelines to treat with diazepam:

- Administer diazepam, 10 mg IM or 5 to 10 mg IV every 5 minutes as needed to terminate the seizures.
- Benzodiazepines may result in respiratory depression, necessitating bag-valve-mask or mechanical ventilation.

Respiratory Agents

Toxic respiratory agents first appeared during World War I as the chemical warfare agents chlorine and phosgene. While respiratory agents primarily cause injury to the respiratory system, the location within the respiratory tract depends upon multiple factors, most importantly the agent's water solubility and particle size.

Signs and Symptoms

Ammonia, sulfur dioxide, hydrochloric acid, and sulfuric acid have large particle diameters and high water solubilities, causing immediate damage to the upper airway, mucous membranes,

and eyes. In an extensive exposure, the gas may penetrate deeper into the lower respiratory tract, resulting in non-cardiogenic pulmonary edema.

Phosgene, ozone, and nitrogen gas possess small particles and low water solubilities, causing significant lower respiratory tract injury. The pulmonary edema that results from exposure to these toxic gases is frequently delayed. Phosgene-induced pulmonary edema is characteristically delayed up to 24 hours (early pulmonary edema suggests a poor prognosis), while that caused by nitrogen oxides may not occur until 72 hours after exposure. Chlorine gas, due to its intermediate water solubility, is unique. It causes immediate ocular and upper airway symptoms, delayed chest tightness, and dyspnea from the pulmonary edema.

Management

- Immediately terminate the exposure by removing the casualty from the environment or placing a chemical weapons mask on the casualty.
- If exposed personnel do not have gas masks, breathing through a damp cloth may significantly reduce airway exposure, especially to highly water-soluble gases.
- Ensure the casualty does not engage in any more physical activity than necessary. Increases in physical activity result in an increased respiratory rate and tidal volume, potentially further exposing the casualty to the toxic chemical or exacerbating any existing pulmonary injury.

Because there are no specific antidotes for toxic respiratory agents, provide supportive care tailored to the patient's symptoms. After removal from the source and decontamination (including eye irrigation), treat the casualty as follows:

- Provide as much supplemental oxygen as necessary to maintain 88% saturation, but do not provide additional oxygen. There is a theoretical risk that supplementing oxygen beyond the minimum necessary to maintain sufficient oxygen saturation could further exacerbate lung injury via free radical generation.

- Provide humidification for upper airway irritation.
- Administer inhaled bronchodilators for bronchoconstriction.
- In the case of chlorine gas exposure, consider nebulized sodium bicarbonate. Chlorine gas reacts with water after inhalation, forming hydrochloric acid, a compound amenable to neutralization with sodium bicarbonate.
- In those casualties who develop noncardiogenic pulmonary edema, use positive pressure ventilation. Diuretics are generally not indicated.
- If the casualty develops breathing difficulty, endotracheal intubation and mechanical ventilation may be necessary.

Cyanide

Chemical asphyxiates, such as cyanide and carbon monoxide, can interfere with oxygen transport and utilization. The use of cyanide as a chemical weapon in combat is limited because it rapidly dissipates in the environment. Therefore, for cyanide to be effective, it must be used in an enclosed environment (eg, building or tunnels with poor ventilation) or ingested in the form of a cyanide salt. Additionally, certain materials (eg, wool, silk, synthetic rubber, polyurethane) generate cyanide when burned, which may poison individuals in enclosed spaces like vehicles or buildings.

Signs and Symptoms

Cyanide blocks aerobic metabolism. Therefore, the symptoms of cyanide poisoning are consistent with cellular hypoxia and include the following:

- Headache.
- Agitation.
- Confusion.
- Lethargy.
- Seizures.
- Tachycardia followed by bradycardia.
- Tachypnea followed by bradypnea.
- Coma.
- Death.

Following inhalation of cyanide, these symptoms are nearly immediate and rapidly progressive. Following ingestion of cyanide, the symptoms may be more delayed and gradual in onset.

While cyanide poisoning is a clinical diagnosis, laboratory analysis will show lactic acidosis with lactate greater than 8 mmol/L (10 mmol/L in smoke inhalation casualties) and elevated venous oxygen saturation.

Note: Because cyanide prevents cells from using oxygen, a cyanide-poisoned casualty will have a pulse oximetry value at or near 100%.

Management

If you suspect exposure to cyanide gas, rapidly remove the victim from the contaminated environment while simultaneously ensuring the safety of other personnel with appropriate personal protective equipment. If you suspect cyanide poisoning from exposure to a liquid or solid form, decontaminate the casualty by carefully removing clothing and flushing skin. Treat cyanide poisoning as follows:

- Hydroxocobalamin is the antidote to cyanide. Administer 5 g IV. If the casualty fails to respond adequately, repeat this dose. Doses up to 20 g have been reported.
- If hydroxocobalamin is not readily available, follow standard ACLS (advanced cardiovascular life support) guidelines until the casualty is transported to a facility with hydroxocobalamin or the antidote is transported to the casualty.

Note: Cyanide-poisoned casualties can survive and remain neurologically intact if they receive hydroxocobalamin even after 30 minutes or more of cardiopulmonary resuscitation.

Blister Agents

Vesicants are agents that induce blistering of the mucous membranes and skin. The two primary vesicants are sulfur mustard and lewisite. Sulfur mustard is a yellow to brown oily liquid, and lewisite is a clear, oily liquid.

Signs and Symptoms

Mustard injures the skin, mucous membranes, and respiratory tract. Injury to these areas often results in incapacitation for several days. Mortality is low at 2% to 3% and likely lower with modern supportive medical care. Delayed symptoms typically occur 4 to 12 hours after exposure. Skin that is thin, moist, and warm is most susceptible (eg, antecubital fossae, axillae, neck, perineum, and scrotum). Signs and symptoms of mustard include the following:

- Skin.
  - Erythema.
  - Vesicles.
  - Bullae.
  - Skin necrosis.
- Ocular.
  - Eye pain.
  - Blurry vision.
  - Corneal damage.
- Respiratory (inhalation).
  - Hoarseness.
  - Cough.
  - Chest pain.
  - Shortness of breath.

Unlike mustard, lewisite exposure results in immediate pain but otherwise has less tissue damage and a more rapid recovery.

Management

The chemical reaction between skin and vesicants occurs within a few minutes. Therefore, decontaminate casualties immediately following exposure. If immediate decontamination was not done, decontaminate casualties to prevent exposure to any agent that has not yet contacted and reacted with human tissue.

Note: Vesicles and bullae do not contain active chemical agents capable of harming other individuals.

Treatment is predominantly symptomatic and supportive and includes the following:

- Treat skin injuries using standard wound management procedures.
- Monitor for secondary wound infections and treat them when identified.
- Provide verbal reassurance for those blinded by injury to the cornea. Blindness is typically temporary.
- In the rare event of significant pulmonary injury, treat with:
  - Supplemental oxygen.
  - Bronchodilators.
  - Non-invasive ventilation.
  - Endotracheal intubation and mechanical ventilation as clinically indicated.

Lewisite chelators exist, but their availability is limited in a PC environment.

Radiation

Ionizing radiation exposure can occur via a nuclear weapons attack or a radiological dispersal device (RDD), often called a "dirty bomb." Whereas detonation of a nuclear weapon generates radioactive particles and energy, an RDD uses conventional explosives to disperse radioactive material. A nuclear weapon results in significantly more morbidity, mortality, and radioactive contamination than does an RDD. Either weapon will cause greater blast and thermal injury as the distance from the explosion decreases.

Signs and Symptoms

Acute radiation syndrome occurs with radiation doses of greater than 100 Roentgen equivalent man (rem). Acute symptoms include the following:

- Nausea.
- Vomiting.
- Diarrhea.
- Fatigue.

As radiation exposure levels increase, the time between exposure and symptom onset decreases. At lower doses, the acute radiation syndrome symptoms will resolve. In moderate doses, a latent period follows the resolution of acute radiation symptoms. The manifest illness stage occurs after the latent period. In severe radiation poisoning, the acute symptoms immediately progress to the manifest illness stage.

There are three manifest illness stages: (1) hematopoietic, (2) gastrointestinal, and (3) central nervous system.

Hematopoietic. Symptoms occur at doses of 100 to 1000 rem. Following acute radiation symptoms, casualties develop bone marrow suppression, which leads to decreased white blood cell production and susceptibility to death secondary to infection. At a dose of 350 rem, 90% of casualties will develop vomiting within 12 hours of exposure. Without supportive care, the mortality rate is 50%. At doses of 500 rem and 1000 rem, even with supportive care, the mortality rates are 50% and 90% to 100%, respectively.

Gastrointestinal (GI). GI damage occurs at doses of greater than 1000 rem. At this exposure, casualties develop the following symptoms within minutes:

- Nausea.
- Vomiting.
- Diarrhea.

A latent period of days to hours follows the acute radiation syndrome. Casualties experience GI symptoms and sepsis after the latent period and die within several days to weeks.

Central Nervous System (CNS). At doses greater than 3000 rems, there is damage to the CNS. The following symptoms occur within minutes of exposure:

- Vomiting.
- Diarrhea.
- Confusion.
- Ataxia.

Casualties die within 24 to 72 hours.

Management

Unless casualties were wearing (or located near) quantitative radiological detection devices, determining the severity of radiation exposure in the field is not possible. Additionally, radiation poisoning symptoms are typically delayed days to weeks after exposure. Therefore, base initial triage on conventional injuries. While GI symptoms (vomiting and diarrhea) are indicators of significant radiation poisoning, nuclear combat's anxiety and mental stressors may also cause severe GI symptoms, making them unreliable predictors of the severity of radiation exposure. Any casualty who develops CNS symptoms is considered expectant. Casualties who sustain both radiological and trauma/burn injuries have markedly increased morbidity and mortality. Use the following guidelines to manage casualties who sustained both radiological and trauma/burn injuries:

- Decontaminate casualties exposed to radioactive particles by disposing of clothing, which removes 90% of the contamination, and thoroughly washing with soap and water (if possible).

Note: Secondary exposure to radiation can occur when treating contaminated casualties; however, the risk of dangerous exposure is extremely low, and lifesaving interventions precede decontamination.

- Thoroughly irrigate all wounds with normal saline or sterile water.
- Close wounds.
- For trauma combined with radiation injury, perform surgical procedures within 36 to 48 hours of radiation exposure, or delay surgery until 2 months after the injury. Radiation exposure inhibits the body's ability to generate new tissue and heal from 2 days to 2 months after the injury.

Treat casualties in the PC setting as follows:

- Provide supportive care.
- Treat concomitant blast and thermal injuries.
- Replace fluid and electrolytes for GI losses.

Biologic Agents

In a PC environment, military personnel are at increased risk for infectious diseases. It will be challenging to determine if illness among combatants is due to natural infections, food- or water-borne illness, or a biological attack.

The following indicate a biological attack:

- Multiple casualties present in a short time.
- Over 50% of personnel develop a given illness.
- Animals die from similar illnesses.
- Detection of a biological weapons attack by a biological identification detection system.

Signs and Symptoms

Signs and symptoms are dependent on the biological agent used and the route of exposure (ie, inhalation, ingestion, cutaneous). While diagnostic tests exist, they are unlikely to be available in the PC setting. Table 4-2 presents pathogen-specific signs and symptoms.

Treatment

If you suspect a biological attack based on circumstances indicating an attack or the alarm of a biological identification detection system, decontaminate personnel with one of the following:

- Wash with soap and water.
- Cleanse with a 0.5 % hypochlorite solution (one part household bleach mixed with nine parts water).

Focus treatment on rapidly administering an appropriate antibiotic (if indicated) and provide supportive care. The severity of illness and the casualties' ability to perform their duties will determine return to duty or evacuation. Additionally, if the agent is contagious, casualties may require separation from other personnel or evacuation to prevent the spread of infection. Use the following protective measures for medical personnel:

Table 4-2. Biological Weapons

Agent	Type	Signs and symptoms	PC management
Botulinum	Biological toxin	Cranial nerve palsies, paralysis, respiratory failure	Supportive care, evacuate for antitoxin
Ricin	Biological toxin	Fever, cough, SOB, arthralgias, pulmonary edema	Supportive care
Anthrax	Bacteria	Fever, malaise, cough, SOB, cyanosis	Ciprofloxacin
Plague	Bacteria	High fever, chills, headache, cough, SOB, cyanosis	Streptomycin
Brucellosis	Bacteria	Fever, headache, myalgias, sweats, chills	Doxycycline
Cholera	Bacteria	Profuse watery diarrhea	Fluid therapy and antibiotics (tetracycline, doxycycline, or ciprofloxacin)
Tularemia	Bacteria	Cutaneous ulcer, lymphadenopathy, fever, chills, headache, and malaise	Streptomycin
Q-fever	Bacteria	Fever, cough, and pleuritic chest pain	Tetracycline
Venezuelan equine encephalitis (VEE)	Virus	Fever and encephalitis (headache, altered mental status, weakness, seizures)	Supportive care
Smallpox	Virus	Malaise, fever, rigors, vomiting, headache followed by pustular vesicles starting centrally and spreading peripherally	Supportive care
Viral hemorrhagic fevers (VHF)	Virus	Flushing of the face, petechiae, bleeding, fever, myalgias, vomiting, and diarrhea	Supportive care

Abbreviation: SOB, shortness of breath.

- Practice hand hygiene after casualty contact.
- Wear gloves when touching blood, body fluids, secretions, excretions, and contaminated items.
- Wear a mask, eye protection, and gown (if available) during procedures likely to generate sprays of blood, body fluids, secretions, or excretions.

If personnel are at risk of exposure to anthrax, plague, Q fever, tularemia, or other serious bacterial infections, chemoprophylaxis with antibiotics may be indicated. See Table 4-2 for pathogen-specific management recommendations.

Summary

For additional chemical, biological, and radiological casualty management guidelines, go to the Joint Trauma System website. https://jts.health.mil/index.cfm/PI_CPGs/cpgs

Chapter 5

TRANSFUSION AND COAGULOPATHY

Andrew D. Fisher, MD, MPAS

Introduction

Over the last 20 years, the United States has enjoyed rapid evacuation from the battlefield. In future conflicts, near-peer multidomain operations (MDO) and large-scale combat operations (LSCO) will likely delay evacuations. Understanding how to optimize resuscitation and transfusion strategies will be key to survival for the maximum number of wounded casualties.

Key Principles

- Hemorrhage leads to coagulopathy, oxygen debt, and blood failure. Addressing these issues early can help restore the functionality of blood.
- Assessing and reassessing casualties to determine their needs is critical, especially for ongoing hemorrhage control and transfusion requirements.
- Follow resuscitation goals using your available resources to facilitate the best patient outcomes.
- Whole blood is the preferred resuscitation fluid in trauma.
- Fresh whole blood (FWB) is the best resuscitation fluid in trauma, but it requires more time and labor to perform adequately.
- If whole blood is not available, use blood products in a 1:1:1 ratio.
- Using an unknown donor is risky; however, there are steps to mitigate the risk and identify the safest donors.

Blood Failure and Physiology

Severe hemorrhage leads to shock that results in blood failure. This state entails oxygen debt, coagulopathy, endotheliopathy, and platelet dysfunction. Additional contributors to blood failure

include acidosis, low cardiac output, fibrinolysis, dilution, and hypothermia. Approximately 25% to 35% of severely injured (injury severity score [ISS] >15) patients develop coagulopathy and blood failure.

The oxygen debt represents the cumulative oxygen deficit. Hemorrhage and hypotension result in insufficient delivery of needed oxygen to the tissues, and anaerobic metabolism becomes the dominant means of producing energy for the body. Fick's equation conceptualizes this physiology: oxygen delivery = 1.34 × hemoglobin × hemoglobin oxygen saturation × cardiac output ($DO_2 = 1.34 \times Hb \times Sao_2 \times CO$).

The endothelial glycocalyx (EG) is a heterogeneous group of proteoglycan core proteins linked with glycosaminoglycan chains that line the luminal side of the vascular endothelium. Breakdown of the EG leads to increased vascular permeability. The following main components cause disruption and destruction of the EG:

- endothelial compromise and paracellular permeability,
- dysfunctional coagulation,
- inflammation, and
- catecholamine surge.

In acute inflammation, which may occur during hemorrhagic shock, endotheliopathy disrupts the subglycocalyx, and plasma proteins leak into the interstitial space.

Calcium plays a vital role in coagulation and clot formation. It helps bind phospholipids and acts as a cofactor at several points in the clotting cascade. The loss of calcium due to administering blood products (where citrate acts by chelating calcium) or through ongoing hemorrhage may lead to clinically relevant hypocalcemia. These low levels of calcium can contribute to ongoing coagulopathy.

Coagulopathy is the greatest concern with blood failure, and it may occur regardless of any treatments provided to the patient. The drivers of coagulopathy include procoagulant-activated protein C, thrombin, anticoagulants, plasmin, and tissue plasmin activator (tPA). Whole blood and plasma can attenuate the endotheliopathy, help restore the EG, and help correct coagulopathy and oxygen debt.

Triggers for Transfusion

Available lab capabilities, diagnostic imaging, and medical responders often constrain prolonged care (PC). Given these limitations, responders can use an acceptable trigger to determine the need for blood transfusion. These triggers are based on physiology, anatomical injuries, the mechanism of injury, and laboratory findings. Using the larger clinical picture and incorporating as much data as possible are best for determining if a casualty requires a transfusion.

Physiologic changes that may indicate a need for a blood transfusion include:

- heart rate,
- blood pressure,
- end-tidal CO_2, and
- respiratory rate.

Many in the Department of Defense (DOD) use the tactical combat casualty care (TCCC) guidelines. The guidelines as of 2022 use:

- a weak or absent radial pulse as an indication of hypotension (systolic blood pressure [SBP] <80 mm Hg) and
- altered mental status in the absence of brain injury as a sign of hemorrhagic shock.

The prolonged field care guidelines use the TCCC triggers to initiate a transfusion. When possible, obtain blood pressure using a blood pressure cuff. This is a more accurate and precise method to determine hypotension. Data from the DOD Trauma Registry show that triggers for transfusion include the following:

- SBP <90 mm Hg and a heart rate >120 beats/min or
- shock index (SI) of >0.9 and pulse pressure <45.

SI = heart rate ÷ SBP and pulse pressure = SBP – diastolic blood pressure

Anatomic injuries and mechanisms of injury with associated wound patterns may also be helpful tools when determining the appropriate time to transfuse. Consider transfusion in patients with:

- penetrating injuries to the torso;
- gunshot wounds;
- blast wounds; and
- traumatic amputation requiring a tourniquet, especially those above the knee or elbow.

Explosives and gunshots cause wounds that may require massive transfusions. Furthermore, amputations above the knee or elbow are significantly associated with massive transfusions.

There are several predictors of massive transfusion available. However, most were developed for use within the hospital or military treatment facilities capable of surgery (Roles 2 to 4). Working outside of the hospital presents several challenges. Still, as point-of-care laboratory testing and ultrasound become more prevalent, consider the following two methods:

1. Early predictors of massive transfusion in combat casualties use hemoglobin ≤11 g/dL, international normalized ratio (INR) >1.5, and a penetrating mechanism to predict the need for massive transfusion.[1]
2. The assessment of blood consumption (ABC) score consists of four components[2]:
   a. penetrating mechanism,
   b. SBP ≤90 mm Hg,
   c. HR ≥120 bpm, and
   d. positive focused assessment with sonography for trauma (FAST).

Available Options

Select blood products with the following priority, subject to availability (per December 15, 2021, TCCC guidelines):

1. Cold-stored low titer group O whole blood (LTOWB).
2. Prescreened LTOWB.
3. Plasma, red blood cells (RBCs), and platelets in a 1:1:1 ratio.
4. Plasma and RBCs in a 1:1 ratio.
5. Plasma or RBCs alone.

When choosing a whole blood product in a PC setting, the following options may be available, listed from most to least preferred:

- Cold-stored LTOWB or fresh LTOWB drawn from prescreened donors at the deployed location, before the mission or during combat casualty care.
- If you have a small group of potential donors, and the donors were identified before deployment, give group-specific whole blood (WB) from prescreened donors. Transfuse group A to group A, group O to group O, and LTOWB to groups B and AB.
- If you have unscreened donors, give group-specific WB for all ABO blood groups. If using this method, ensure proper screening and use an Eldon card or other approved ABO testing kit before collecting and transfusing.

WB is the primary recommended resuscitation product for hemorrhagic shock, with LTOWB preferred. LTOWB may be transfused as cold-stored or fresh. Cold-stored LTOWB is a US Food and Drug Administration (FDA) approved product that the Armed Services Blood Program (ASBP) can supply and ship from the continental United States. In a deployed setting, non-FDA-approved cold-stored LTOWB can be drawn from identified and screened donors. Before deployment, coordinate with the ASBP and local military blood donation center to identify donors. All personnel with group O blood require testing for immunoglobulin M (IgM) anti-A and anti-B antibodies. A low titer is an IgM anti-A and anti-B ratio less than 1:256. Testing for transfusion-transmitted diseases (TTDs) before deployment is also mandatory. Theater Medical Data Store (TMDS) is the system of record for documenting the results of these tests.

Cold-stored LTOWB may be stored for 21 to 35 days, depending on the solution (Table 5-1). Citrate-phosphate-dextrose (CPD) collection bags have a 21-day shelf life. Citrate-phosphate-dextrose adenine solution (CPDA-1) has a 35-day shelf life. Both solutions are stored between 1 to 6 °C. LTOWB is optimal because it can be transfused to all ABO blood-type groups with low risk of a severe reaction. If a non-ABO patient receives a massive transfusion using only LTOWB, do not administer group-specific blood for at least 2 weeks. Warm any cold-stored blood product using an appropriate fluid warmer before administration.

Table 5-1. Storage Parameters for Whole Blood and Blood Component Products[a]

Product	Volume (mL)	Shelf life	Temperature		Transport	
			Storage	Transport	Bulk storage requirements (eg, Collins box)	Tactical[b] (storage time when preconditioned to ≤ –18 °C)
Warm FWB	450	24 h at RT	1-6 °C	N/A	N/A	2 units: 24-48 h
CSWB (LTOWB)	450-500	24 h at RT: CPD: 21 d CPDA-1: 35 d	1-6 °C	1-10 °C	21 units/box: ~14 lb wet ice every 48 h	2-4 units (depending on container): 24-48 h
Red blood cells	310	CPD/AS5: 42 d CPDA-1: 35 d	1-6 °C	1-10 °C	30 units: ~14 lb wet ice every 48 h	Frozen: N/A
Frozen plasma	220	Frozen: 1 y	Frozen: ≤ -18 °C	Frozen: keep frozen	Frozen: 15 units (~20-30 lb dry ice every 48 h)	Thawed: 2-4 units depending on container (24-48 h)
Liquid plasma	220	CPD: 26 d CPDA-1: 40 d	Thawed: 1-6 °C	Thawed: 1-10 °C	Thawed: 30 units (~14 lb wet ice every 48 h)	2-4 units depending on container: 24-48 h

(**Table 5-1** *continues*)

Table 5-1 *continued*

Product	Volume (mL)	Shelf life	Temperature		Transport	
			Storage	Transport	Bulk storage requirements (eg, Collins box)	Tactical[b] (storage time when preconditioned to ≤ –18 °C)
Freeze-dried plasma	220	2 y	2–25 °C	Ambient temperature	30 units: ~14 lb wet ice every 48 h	2 units: 24-48 h
Platelets, RT	150-400	5-7 d	20-24 °C	20-24 °C	N/A	N/A
Platelets, cold-stored	150-400	10-14 d	1-6 °C	1-10 °C	4 units: ~14 lb wet ice every 48 h	1-10 °C
Cryoprecipitate	15 (single) 150 (pooled)	Frozen (single & pooled): 1 y Thawed: within 6 h single or 4 h pooled if stored at 20-24 °C	Frozen: ≤ -18 °C Thawed: 20-24 °C	Frozen: keep frozen	Frozen: 15 units (20-30 lb dry ice every 48 h)	NA

Abbreviations: AS5, adenine-saline; CPD, citrate-phosphate-dextrose; CPDA-1, citrate-phosphate-dextrose-adenine; CSWB, cold-stored whole blood; FWB, fresh whole blood; LTOWB, low titer group O whole blood; N/A, not applicable; RT, room temperature.
[a] Approximate distribution of blood types in the US population: group O, 45%; group A, 40%; group B, 11%; group AB, 4%.
[b] Tactical blood storage options include the Golden Hour Container and Golden Hour Medic Container. Other transport containers may also be available. Ensure all blood transport containers are validated in coordination with the Armed Services Blood Program.

When cold-stored LTOWB is not an option, FWB is preferred. FWB is blood collected and transfused within 24 hours. FWB is the ideal resuscitation fluid; however, it takes time to collect. It has been used in US conflicts since World War I. FWB retains its hemostatic and oxygen-carrying capability. Studies from Afghanistan and Iraq have demonstrated the superiority and survival benefits over stored blood products.

The separation of WB into its components of RBCs, plasma, and platelets (PLTs) has benefits outside of trauma. Transfusion of specific blood components may be used in cancer, anemia, or coagulation-disorder patients. In some situations, components may be available to PC providers in addition to WB or as the only available blood products. However, components are more challenging to store and transfuse than cold-stored WB. When components in a 1:1:1 ratio are compared with WB, outcomes are similar. Evidence suggests that WB or components in a 1:1:1 ratio improve early (0-6 h) survival rates. This time frame encompasses early PC, so transfusion with either may improve casualty outcomes.

RBCs are typically stored at 1 to 6 °C and have a shelf life of 42 days. It is often the first component transfused. During MDO or LSCO, frozen RBCs may be the only option available. Frozen RBCs may be stored for 10 years at <65 °C. Once thawed, they may be used interchangeably and successfully with standard RBC units when needed.

Plasma may be frozen, then thawed. Store plasma like RBCs: at 1 to 6°C or "freeze-dried" lyophilized. Freeze-dried plasma has been used since World War II and has a substantial shelf life. The French freeze-dried plasma has been used within the special operations community since 2011 with varying success. Limitations of the French product are due to the large, vacuum-sealed glass bottles. A current effort is to manufacture and mass produce a US freeze-dried plasma product. Frozen plasma may be stored for up to one year. If available, this product must be used within 6 hours of thawing or, if pooled, within 4 hours at 20 to 24 °C.

PLTs are usually kept at room temperature for 5 to 7 days before expiring. It is unlikely these PLTs would be available in the far-forward setting. However, more recently, cold-stored PLTs have become an option for the battlefield. They may be stored at 1 to 6 °C for 10 to 14 days.

Goals for Transfusions

The basis of transfusion goals includes physiologic and laboratory findings. When using WB, aim for an SBP of 100 mm Hg and a heart rate of <100 beats per minute, or an SI of <1. Lactate is a good anaerobic metabolism measure but requires trending for at least 1 hour. If the casualty has a traumatic brain injury (TBI), an SBP of 110 mm Hg is more appropriate. However, treating severe TBIs in an MDO or LSCO may not be the most efficient way to save the greatest number of casualties. If you can use an arterial line, a mean arterial pressure (MAP) of >65 mm Hg is an option. The goals for transfusion are not codified as requirements. Data from repeated assessments of your casualty to determine their transfusion and resuscitation needs may not match these recommendations.

Contingency Options

When LTOWB, components, or screened identified donors are not available, using unknown donors is necessary. An inherent risk is associated with using donors without TTD testing. At a minimum, the ability to confirm ABO is mandatory. The Trauma Hemostasis and Oxygenation Research (THOR) Network developed an austere screening tool to identify the safest donors (Exhibit 5-1). In these situations, it is critical to have a volunteer group that offers the least risk to your patients. Furthermore, since these are not vetted donors, complete a donor assessment for each volunteer that is as thorough as possible.

Exhibit 5-1. Unscreened Blood Donor Procedures

Primary Triage:

Question as a group.

Serial	Question	Yes	No	Action
1	Do you want to give blood?			Disqualify if NO
2	Have you given blood before?			If YES, consider early selection
3	In the past 48 hours, have you taken aspirin, Motrin, or other NSAIDs?			If YES, donor priority is after those who answer NO

Secondary Triage:

Question potential donors individually.

Serial	Question	Yes	No	Action
4	Are you unwell now? New fever/diarrhea/vomiting Chronic medical condition and not well			Disqualify if YES
5	Have you ever had cancer, heart problems, bleeding conditions, or lung disease?			Disqualify if YES

(**Exhibit 5-1** *Continues*)

Exhibit 5-1 *Continued*

Serial	Question	Yes	No	Action
6	Have you had a blood transfusion or blood products in the last year?			Disqualify if YES, accept after 1 year
7	Are you living with hepatitis B or C, HIV/AIDS, OR living with anyone with these conditions?			Disqualify if YES
8	Have you ever been refused as a donor or told not to donate blood? (history of treated anemia may be acceptable)			Disqualify if YES
9	Male donors only: Have you ever had sex with another male?			Disqualify if YES
10	Have you ever used needles to take drugs, steroids, or anything not prescribed by your doctor?			Disqualify if YES
11	Are you currently pregnant or breastfeeding?			Disqualify if YES
12	Conduct a physical examination. Check temperature/ rash/malnutrition/pallor/jaundice/cyanosis/shortness of breath/ intoxication from alcohol or drugs/veins			Disqualify any potentially unwell donor or donors with very difficult veins
13	Have you ever had malaria, Chagas, or babesiosis?			Disqualify if YES

(**Exhibit 5-1** *Continues*)

Exhibit 5-1 *Continued*

Serial	Question	Yes	No	Action
14	Have you ever received money, drugs, or other payment for sex?			Disqualify if YES

Scoring

Add up scores and record the total: Lowest score = Lowest risk. Use point-of-care test for transfusion-transmitted infections. Eliminate and counsel any positives. Blood type both donor and recipient, and document results.

Score	Questions	Subtotal	Notes
Blood donation history			
1	Regular donor		Optimal
2	Previous donor		
3	Nondonor		
Veins and body weight			
1	Good lateral (outer) vein		Optimal
2	Poor or difficult vein		
3	<60 kg		

(**Exhibit 5-1** *Continues*)

Exhibit 5-1 *Continued*

Score	Questions	Subtotal	Notes
Travel			
1	No travel in the countries below in the last 6 months		Optimal
2	South America		
4	Asia and Africa		
Lifestyle			
1	Sex with one partner		Optimal
3	Sex with multiple partners but protected		
—	Sex with a sex worker or in exchange for money or drugs		Avoid for 12 months
Serious medical conditions			
1	None		Optimal
3	Past or present serious medical conditions but managed and well		
3	Untreated current medical conditions but well		
	TOTAL		

Adapted from: Douhty H, Thompson P, Cap AP, et al. A proposed field emergency donor panel questionnaire and triage tool. *Transfusion*. 2016;56:S119–S127.

Expectation Management

Look beyond your capabilities and understand your unit's capacity. In an MDO or LSCO, casualties will die, and understanding the importance of triage and logistical limitations will ultimately save lives. When faced with several casualties, triage patients based on who will benefit the most. Types of injuries and patient presentations that should be considered as expectant or less likely to survive include the following:

- Penetrating skull wound with exposed brain matter.
- Severe TBI with signs of herniation (dilated pupils and hypertension plus bradycardia).
- Glasgow Coma Scale score of 3 to 5.
- Penetrating thoracic or abdominal injuries that do not respond to two units of blood and remain hypotensive.
- Junctional amputations with pelvic disruption.

For casualties who present in cardiac arrest possibly due to tension pneumothorax, perform bilateral decompression with a needle or simple thoracostomy. If there is no response, cease efforts, especially if surgical resuscitation is more than 10 minutes away.

Summary

The care of combat casualties can be daunting and is exponentially more difficult when there are several severely wounded individuals, especially when medical evacuation is limited, delayed, or unavailable. Knowing how to triage appropriately and identify those who will benefit from resuscitation and interventions is crucial. Understanding the pathophysiology of hemorrhagic shock and blood failure can be helpful when resuscitating casualties.

Restoring the functionality of blood is vital to survival and can be accomplished using models that predict the need for transfusion to allocate the limited amount of blood products best. FWB is ideal but takes time to collect. Cold-stored WB is now available across the DOD and is the first choice when resuscitating casualties. Cold-stored WB provides expedient resuscitation and allows FWB donors to remain viable contingencies.

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Chapter 6

MECHANICAL VENTILATION

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Introduction

Mechanical ventilation is an invasive modality that facilitates gas exchange in critically ill patients who cannot maintain their airway or adequately meet oxygenation and ventilation goals. Ventilatory management is resource intensive, with unique risks and complications that may not be appropriate for all resource-limited situations. Nonetheless, understanding several foundational concepts of mechanical ventilation can minimize iatrogenic injury while optimizing the chances for recovery. A basic approach to the initial management of the ventilated patient during prolonged care (PC) for non-critical care trained medical professionals is essential. Initial ventilator management will save lives while awaiting patient transport to higher roles of care or expert consultation within a resource-limited environment.

Key Principles

- The primary strategy for mechanical ventilation in a resource-limited environment is the conservation of oxygen due to concentrator availability, electrical supply, and equipment.
- Understanding foundational concepts of mechanical ventilation can minimize iatrogenic injury while optimizing the chances for recovery.
- Many unique challenges may arise while providing mechanical ventilator support in a PC setting, including competing missions, threats of direct and indirect fire, weather, resupply, capacity, and personnel limitations.
- Ventilatory management is resource intensive with unique risks and complications that may not be appropriate for all resource-limited situations; discuss triage considerations

regularly in every instance, due to the required resources to maintain an individual on mechanical ventilation.
- Despite the best capabilities and resources, the care of an individual on mechanical ventilation in a PC setting inevitably requires patient transport to a higher level of care.

Definitions

Compliance. The ease with which the lung stretches and the chest wall and diaphragm accommodate, measured as the change in volume relative to a change in pressure.

Elastic pressure. The pressure required to expand lung tissue, expand the chest wall, and deflect the diaphragm.

Peak (inspiratory) pressure. The maximum pressure generated during breath delivery.

Plateau pressure. A measure of the end-inspiratory distending pressure. The pressure in distal small airways and alveoli is a surrogate for lung compliance.

Refractory hypercapnia. Inadequate clearance of carbon dioxide (CO_2) resulting in respiratory acidosis (pH ≤7.20) despite maximally tolerated lung-protective ventilator settings.

Refractory hypoxemia. The partial pressure of arterial oxygen (Pao_2) ≤60 mm Hg or a Pao_2/Fio_2 ratio ≤100 with a fraction of inspired oxygen (Fio_2) of 0.8 to 1.0, with positive end-expiratory pressure (PEEP) of >15 cm H_2O for more than 12 hours despite lung-protective low tidal volumes of 4 to 6 mL/kg.[1]

*Resistance***.** The opposition of gas flow, measured as the ratio between the pressure driving a given flow and the resulting flow rate.

Resistive pressure. The pressure required to overcome resistance to airflow in patient airways and the endotracheal tube (ETT).

Manual Ventilation

Mechanical ventilation involves using a mechanical ventilator to deliver positive-pressure breaths to a patient. By contrast, manual ventilation uses a circuit with a self-inflating or flow-inflating bag

that is compressed by hand. Manual ventilation can be used when a mechanical ventilator is not available, when troubleshooting a mechanical ventilator, or in the immediate period around airway management. Ideally, use a PEEP valve and supplemental oxygen.

Key advantages of manual ventilation include using a mask with the circuit before placing a more advanced airway and estimating ventilatory compliance based on how easy or difficult it is to compress the bag and produce chest rise. Key disadvantages include a risk of esophageal and gastric insufflation with prolonged manual ventilation via a mask; a risk of leakage around an inadequate mask seal causing hypoventilation; and an inability to assess tidal volumes and airway pressure, potentially causing hyperventilation, barotrauma, or volutrauma. Additionally, manual ventilation is labor intensive, requiring at least one person to compress the bag continuously. Use a mechanical ventilator in a patient requiring continuous assisted ventilation when possible.

Airway Management for Mechanical Ventilation

Assessing a patient's airway and performing any indicated interventions are required before evaluating a patient's ventilatory status, as demonstrated with the placement of "A" for airway ahead of "B" for breathing in the TCCC ABCDE (tactical combat casualty care airway, breathing, circulation, disability, exposure) algorithm. While some patients may need airway intervention without the institution of mechanical ventilation, all patients requiring mechanical ventilation require airway intervention first. The field approach to airway management alone is best described in the TCCC handbook and the Airway Management in Prolonged Field Care Clinical Practice Guideline (CPG). However, selecting an airway management technique has implications for mechanical ventilation.

A mechanical ventilator can be used with three airway techniques: (1) a supraglottic airway (SGA), (2) an ETT, or (3) a surgical airway.

Supraglottic Airway

Available in multiple brands and styles, an SGA functionally serves as an advanced oropharyngeal airway while also providing a seal in the hypopharynx that occludes the esophageal inlet. Use an SGA with either manual or mechanical ventilation. An SGA is easy to place in most patients and is a crucial adjunct for a difficult *can't intubate, can't oxygenate* airway scenario. Because an SGA does not secure the airway below the glottis, it is not a definitive airway and is not an appropriate choice for patients at risk of airway edema, such as patients with severe burns, anaphylaxis, or airway trauma.

Risks. Important considerations for SGAs in the PC scenario include the following:

- Aspiration. Despite the theoretical occlusion of the esophageal inlet, air could pass into the esophagus, causing gastric distention and increasing the risk of aspiration. The glottis and trachea are also not protected in the event of aspiration. While early-generation SGAs produced a less reliable seal during positive-pressure ventilation, current SGAs safely produce a seal against inspiratory pressures at least as high as 15 cm H_2O. However, their use remains *relatively contraindicated in trauma patients* due to the increased risk of aspiration in this patient population.[2]
- Laryngospasm. Laryngospasm is an involuntary partial or total closure of the true vocal cords, most commonly occurring in inadequate analgesia or sedation. Manifestations could include stridor (partial laryngospasm only), inability to ventilate, very high airway pressures, hypoxia, and chest wall retractions. Treatment includes deepening sedation and providing sustained positive pressure.
- Displacement. The proper functioning of an SGA depends on proper placement. While an SGA can be taped or tied in place, it remains more prone to accidental displacement, particularly during patient movement and transport, than an ETT or surgical airway. Signs of displacement include an audible leak (hissing noise), inadequate tidal volume, and hypoxia.

Note: SGAs are used routinely for procedures lasting 3 to 4 hours, but case reports have discussed the safe use of modern SGAs for up to 24 hours in adults and several days in children. Prolonged use may cause a pressure-related injury to the lingual nerve and tongue.

Practical Tips.

- Use an SGA for the shortest time possible while planning for definitive airway management.
- Allow spontaneous ventilation if possible.
- Use the lowest airway pressures possible to achieve adequate ventilation.
- Consider placing an orogastric tube (choose size 12 Fr or 14 Fr) through a gastric tube outlet.
- In the event of aspiration (gastric or intestinal contents seen in the SGA lumen or the mouth), remove the SGA and suction thoroughly.
- Continually assess the adequacy of ventilation with particular attention to the risks of laryngospasm and SGA displacement.

Endotracheal Tube

An oral or nasal ETT is the most common airway adjunct used during mechanical ventilation. However, placing an ETT is the most challenging of these techniques to perform consistently and correctly, which may limit its use in the PC setting. Additionally, placing and maintaining an ETT through the glottis is very stimulating to the patient, leading with higher sedation requirements when an ETT is used compared with either an SGA or surgical airway. Unique considerations when using an ETT include the following:

- Ensuring adequate ETT depth. An ETT that is too deep can lead to a mainstem intubation with inadequate oxygenation and ventilation, and an ETT that is too shallow manifests as extubation or a large leak. The relative location of the ETT can change with situations such as patient coughing, changes in facial and airway swelling, and patient head flexion or extension.

- Kinking or patient biting on the ETT. A bite block is necessary to reduce the risk of irreversible damage to the ETT and the harm associated with a patient's inspiratory effort against an obstructed tube. A roll of gauze (thicker than the ETT) between the molars is an effective bite block. Monitor the tube for any kinking that prevents effective airflow.

Surgical Airway

Surgical airway techniques include a needle cricothyroidotomy, percutaneous or surgical cricothyroidotomy, and percutaneous or surgical tracheostomy. A standard oral ETT or a tracheostomy tube can be placed and connected to a mechanical ventilator. A major advantage of surgical airway access is improved patient comfort, significantly reducing sedation requirements. This technique also can be used in the absence of either mechanical or manual ventilation for patients with airway, but not breathing, concerns (eg, facial trauma and upper airway edema). Patient tolerance limits the use of either an SGA or ETT in this manner. Specific considerations when using a surgical airway include the following:

- Management of tube displacement. Displacement of a new (<10 d old) surgical airway is a surgical emergency. Replacing the tube through the stoma may not be successful, instead creating a false tract. If a provider experienced in managing new surgical airways is not readily available and the patient cannot oxygenate and ventilate adequately, place an occlusive dressing over the stoma while performing mask ventilation, placing an SGA, or conducting endotracheal intubation.[3]
- Accidental disconnection. A properly placed tracheostomy tube lies flush against the neck. As a result, if the weight of a ventilator circuit is not offloaded, accidental disconnects are likely to occur. Consider placing a straight connector between the tube and the circuit to allow for more circuit slack; however, this maneuver does increase dead space in the circuit and may not be appropriate for all patients. Clamping the tracheostomy tube before any planned circuit disconnects is impossible, which may result in significant de-recruitment in some patients requiring high PEEP.

- Cuff management. Unlike an ETT or SGA, a tracheostomy tube may remain in place with a deflated cuff. When the cuff is not occluding the rest of the trachea, air can flow around the tube and through the vocal cords, allowing the patient to breathe normally and vocalize. However, positive pressure cannot be reliably provided when the cuff is not occlusive. When switching between positive pressure and spontaneous ventilation, it is essential to check for the presence of a cuff and the cuff pressure.

Note: The remainder of this chapter assumes that mechanical ventilation occurs through an ETT, though the material can also be applied to ventilation through an SGA or surgical airway.

Fundamentals of Mechanical Ventilation

Indications

Consider mechanical ventilation when clinical or laboratory-based evidence suggests a patient cannot facilitate adequate oxygenation and/or ventilation or can no longer protect their airway. This decision centers on clinician judgment regarding a patient's condition, and the potential clinical course. There are no simple numeric criteria; however, findings of concern include the following:

- Sustained respiratory rate (RR) >30 breaths per minute with evidence of fatigue.
- Inability to maintain an arterial oxygen saturation (blood gas or pulse oximetry) above 90% with more than 60% supplemental oxygen.
- pH <7.25 and a $Paco_2$ >50 mm Hg.
- Central nervous system injury or pathology resulting in a depressed Glasgow Coma Scale is generally described as 8 or less.

Mechanical Ventilator Breaths

Mechanical ventilation is a regulated increase in airway pressure that generates an increase in lung volume (or "breath") based on the compliance of the lung and resistance of the airway system.

These two features are unique to each patient and are influenced by the disease state that resulted in intubation. Together, compliance and resistance contribute to the lung's response to mechanically delivered ventilation.

Mandatory Breaths. The ventilator functions independently of the patient's effort to provide a set number of breaths per minute. The ventilator controls the characteristics of the breath. It actively initiates the respiratory cycle, while the patient is the passive receiver.

Assisted or Controlled Breaths. The ventilator detects the patient attempting a breath (trigger) and then provides a fully supported breath based on set parameters. The trigger can be either a negative deflection in measured airway pressure or an inspiratory flow. The breath continues until cycle parameters are met—either a set inspiratory time in pressure control or a volume of air delivered in volume control. When the patient starts a breath, the ventilator takes over and delivers a controlled breath.

Supported (Spontaneous) Breaths. The ventilator detects the patient's attempt to breathe (like an assisted breath) and increases airway pressure to a set value. This value is maintained until patient inspiratory effort ceases, providing partial support. The patient starts and terminates the breath and does some of the work with assistance from the ventilator.

Mechanical Ventilator Breath Delivery

Volume Breaths. A preset tidal volume (TV) is delivered once the ventilator is triggered (either mandatory if the patient rate falls below the set rate or patient assisted/controlled). The volume generated is set by the operator (independent variable) and is controlled by regulating the airflow. However, the amount of pressure (dependent variable) required to provide that given volume is a function of lung compliance and resistance within the airway circuit. In a volume-based ventilation mode, it is essential to monitor the pressure generated to avoid ventilator-induced lung injury. The pressure displayed on most ventilator models is the peak inspiratory pressure, which reflects both the lung's resistive and elastic pressure. An additional pressure of

great importance is the plateau pressure (Pplat) (in the smaller, distal airways and alveoli), obtained by performing an "end-inspiratory hold maneuver." In general, maintain the Pplat at less than 30 cm of water to minimize the risk of ventilator-associated lung injury.

Pressure Breaths. A preset pressure is generated once the ventilator is triggered (either mandatory or patient assisted/controlled), which is then sustained for a set time (inspiratory time) before cycling to exhalation. The predetermined pressure (independent variable) will generate a TV (dependent variable) based on lung compliance and airway resistance. The resulting volume attained is a factor of the compliance of the patient's lungs, which can change both acutely and throughout a patient's critical illness. A set minute ventilation (RR × TV) is not guaranteed, so the patient must be monitored for both hypoventilation and hyperventilation. Ensure that breaths generally remain less than 8 cc/kg ideal body weight (IBW) to minimize the risk of lung injury.

Ventilator Modes and Initial Setup

Volume Assist Control

RR, TV, PEEP, and the amount of FIO_2 are manually set in this mode. The "Control" portion guarantees that all breaths are of the set TV—this is regulated by mandating air flow during the breath. The "Volume Assist" denotes that a breath can be triggered by patient effort or time if the spontaneous rate falls below the set rate. A volume-based mode allows the provider to ensure that the patient's minute ventilation does not fall below a set value (set RR × TV in cc/kg of IBW), reducing the potential for volume-based lung injury.

There are two main disadvantages of a volume control mode:

1. It provides a constant flow rate at which the breath is non-physiologic and can cause patient discomfort.
2. The TV delivered can still generate injurious airway pressures, depending on the patient's respiratory physiology and mechanism of injury.

Pressure Assist Control

RR, pressure, PEEP, and FIO_2 are manually selected in this mode. The "Control" and "Assist" are like the volume assist control, except that every triggered breath will result in a set pressure being delivered to the patient for a set time. The advantages of a pressure control mode include a decelerating inspiratory flow pattern that is more physiologic and can prevent pressure injury to the lung (barotrauma).

The main disadvantage is the need for close monitoring to ensure the delivery of adequate volumes. Lung compliance and resistance are dynamic throughout a respiratory injury, and their fluctuation will greatly impact the size of the TV generated for a given set inspiratory pressure. Additionally, the patient's effort will significantly affect TVs, which vary based on sedation and will be absent if the patient is medically paralyzed.

Pressure Support

In this mode, manually selected pressures provide continuous support (Continuous Positive Airway Pressure) or dynamic support throughout the respiratory cycle (Inspiratory and Expiratory Positive Airway Pressure). Since the patient must initiate each breath, do not use pressure support in patients who are not breathing spontaneously. The set inspiratory positive airway pressure (IPAP) support augments the patient's breathing effort to generate an enhanced TV and helps the patient meet ventilation goals. While the expiratory positive airway pressure (EPAP) may be manipulated to augment oxygenation, increasing the delta or driving pressure (IPAP-EPAP) augments the patient's minute ventilation and assists in the patient's breathing. The support duration differs from a pressure-controlled breath (time-based delivery) in that IPAP support terminates when the inspiratory flow rate generated by the patient decreases to a percent of the peak flow (typically a decrease of 25%). This mode is generally the most comfortable for the awake patient and is commonly used to assess a patient's respiratory status before extubation.

Special Modes and Hybrid Modes

Modern ventilators are capable of several other modes, some of which are unique (eg, Synchronized Intermittent Mandatory Ventilation) and others that are combinations of the modes mentioned above (eg, Pressure Regulated Volume Control). There are no data supporting one mode over another; therefore, it is more important to understand the benefits and limitations of the mode being used and ultimately select a mode that the operator is the most comfortable with to achieve their patient-specific goals.

Initial Settings

Follow this procedure to set the mechanical ventilator:

1. Choose the mode of ventilation. See the section above for mode descriptions and their key advantages and disadvantages.
2. Set oxygenation parameters.
   a. *F_{IO_2}* ranges from 21% to 100%. If feasible, place a newly intubated patient on 100% F_{IO_2} for a brief period and then quickly decrease it to 40% to 50%. The goal is to provide the minimum amount of F_{IO_2} (ideally <60%) to maintain an oxygen saturation (Spo_2) between 88% and 95%.
   b. *PEEP* (extrinsic positive pressure applied at the end of a breath to reduce airspace closure during the respiratory cycle) limits atelectasis and improves oxygenation, which can decrease atelectotrauma, and the amount of F_{IO_2} needed. However, excessive amounts of PEEP can both impede venous blood return (leading to hypotension) and cause lung injury through overdistention. Generally, the initial PEEP setting is between 5 and 8 cm H_2O and adjusted based on oxygenation needs. Adjust PEEP and F_{IO_2} in concert to meet oxygenation goals. The commonly available ARDSNet protocol provides a rational framework to help balance PEEP and F_{IO_2}.[4]

3. Set ventilation parameters.
    a. *TV* is commonly set based on a lung-protective strategy of 6 to 8 cc/kg of IBW. IBW is based on a patient's height (in inches) and not their actual weight.
        i. For males: IBW = 50 + 2.3 (height – 60)
        ii. For females: IBW = 45.5 + 2.3 (height – 60)
    b. Once the TV is set, choose the initial *RR* in an attempt to match the patient's minute ventilation needs according to their pre-intubation physiology. For instance, a patient intubated for low pH will likely need a higher minute ventilation to prevent worsening acidemia. Conversely, a patient intubated for airway protection due to depressed mental status may only need settings that result in a physiologically normal minute ventilation (eg, 5-8 L/min).
4. Set other parameters.
    a. Set the *inspiratory flow rate*, generally at 60 L/min. It can be increased to 120 L/min (typically in patients with obstructive lung pathology, such as chronic obstructive pulmonary disease, who need more time for exhalation).
    b. Set the *I:E ratio* (inspiratory time to expiratory time ratio), generally at 1:3. It can be adjusted to 1:4 (typically in patients with obstructive lung pathology who need more time for exhalation). To prolong inspiratory time, the I:E ratio may be reduced to 1:1 in patients with oxygenation issues.
    c. Set *trigger sensitivity*. This is the amount of patient-generated negative pressure or inspiratory flow required to trigger a ventilator to deliver a breath. If the sensitivity threshold is too high, a weak patient will not be able to trigger a breath. Conversely, overventilation can occur if the sensitivity threshold is set too low.

Patient and Ventilator Monitoring

- Assess non-ventilator clinical signs often. Vital signs, mental status, and changes in respiratory effort are all essential for timely identification of significant changes in clinical status.

- Monitor *Spo_2*. The portable pulse oximeter is a continuous and noninvasive monitor that closely correlates with the oxygen saturation of a patient's blood (Sao_2). The optimal target is 88% to 95% to avoid the risks of both hypoxia and hyperoxia and to conserve resources required for oxygen supplementation.
- Monitor *end-tidal CO_2 ($Etco_2$).* This measurement of the CO_2 concentration in exhaled gas closely estimates the alveolar partial pressure of carbon dioxide (Pco_2) concentration in healthy patients. A normal gradient is 3 to 7 mm Hg. Unfortunately, patients with a respiratory disease requiring mechanical ventilation often have increased alveolar dead space, which results in a greater difference between the $Etco_2$ at exhalation and the alveolar CO_2. Consequently, it is more important to monitor the trend of the $Etco_2$ over time and periodically assess venous blood gas to confirm the differences.
- Maintain *ETT cuff pressure* between 20 and 30 cm H_2O. This assists in preventing upper respiratory tract secretions from entering the lungs and maintaining the airway pressure provided by the ventilator.
- Assess *patient-ventilator synchrony* by evaluating the following:

Note: Extended time with a cuff pressure exceeding 30 cm H_2O may result in a pressure-induced ischemic injury of the trachea.

  - Breath delivery occurs rapidly when a patient attempts to trigger a breath.
  - Exhalation is completed before the ventilator attempts to provide a subsequent breath.
  - The flow volume and pressure vs. time loops are smooth.

Dyssynchrony can lead to increased work of breathing and prolonged mechanical ventilator duration. Management options include adjusting pain control or sedation level and adjusting the ventilator to change the speed and/or time that a breath is delivered.

- Maintain *TVs* between 4 and 8 cc/kg of IBW for most patients. The exact volume goals will vary based on the reason that the patient was intubated (eg, lower volumes for patients

with acute respiratory distress syndrome [ARDS] and higher volumes for patients with severe metabolic acidosis).
- Monitor *peak pressure*. The venitilator displays this value during a respiratory cycle, which represents the pressure within the large airways.
- Measure *Pplat* by completing an "end-inspiratory hold maneuver" (pause the ventilator at the end of inspiration to allow the airflow in the lungs to stop and pressure within the circuit to equilibrate). Maintain the Pplat at less than 30 cm H_2O to avoid iatrogenic pressure injury (barotrauma).

Optimization for Refractory Hypoxemia and Hypercapnia

In the deployed setting, where PC is anticipated, managing refractory hypoxemia and hypercapnia in mechanically ventilated patients is essential due to potential logistical challenges whereby evacuation may not be feasible. Although mechanical ventilation allows for the maintenance of gas exchange until the patient's clinical condition improves, it can also injure the lung if appropriate ventilator strategies are not used. Patients who experience refractory hypoxemia and hypercapnia despite optimal ventilator settings are particularly prone to ventilator-induced lung injury.

Management of Refractory Hypoxemia

Refractory hypoxemia is a well-established emergency encountered in critically ill patients who require mechanical ventilation for ARDS, and it is associated with substantial mortality.[5] If hypoxemia persists despite a lung-protective ventilation strategy, attempt rescue therapies to improve oxygenation and stabilize the patient. Rescue therapies present a clinical challenge that involves weighing the associated risks and benefits and requires an in-depth understanding of the inherent therapeutic limitations.

Ventilator Troubleshooting. The first step in managing patients who experience respiratory deterioration during mechanical ventilation is troubleshooting the ventilator and ETT to evaluate for evidence of equipment malfunction or dysfunction, and displacement. Useful references include the DOPES and DOTTS mnemonics that are discussed in more detail below.

Increasing Oxygenation. Oxygenation goals in patients with ARDS are generally accepted as Pao_2 of 55 to 80 mm Hg or Spo_2 of 88% to 95%. In patients who do not meet these goals, increase the PEEP and FIO_2 stepwise according to the ARDSNet protocol (Table 6-1).[4] Both the higher and lower PEEP strategies are reasonable approaches.

Neuromuscular Blockade. Paralysis via neuromuscular blockade (NMB) can be a useful adjunct for patients with refractory hypoxemia. NMB can improve oxygenation by optimizing ventilatory synchrony and reducing metabolic demands (CO_2 production and O_2 consumption). Despite the potential benefits, there are significant limitations, which include:

- Risk of myopathy.
- Impaired ability to perform a neurologic examination.
- The requirement for deep sedation.

Table 6-1 Adult Positive End-Expiratory Pressure Titration Table[a]

Lower PEEP/higher FIO_2								
PEEP (cm H_2O)	5	8	10	12	14	16	18	18-24
FIO_2 (%)	0.3-0.4	0.4-0.5	0.5-0.7	0.7	0.7-0.9	0.9	0.9	1.0
Higher PEEP/lower FIO_2								
PEEP (cm H_2O)	5-12	16	18	20		22		24
FIO_2 (%)	0.3	0.4	0.5	0.5-0.8		0.8-1.0		1.0

Abbreviations: FIO_2, fraction of inspired oxygen; PEEP, positive end-expiratory pressure.

[a] This table identifies two strategies for adjusting PEEP and FIO_2 synchronously in discrete steps, depending on whether the patient's clinical status indicates a higher PEEP or lower PEEP strategy as the optimal management of the patient's acute respiratory distress syndrome.

Adapted from National Institutes of Health-National Heart, Lung, and Blood Institute Acute Respiratry Distress Syndrome Network (ARDSNet). Ventilator Protocol. ARDSNet; 2008. Accessed January 1, 2024. https://www.ardsnet.org/files/ventilator_protocol_2008-07.pdf

Therefore, use NMB judiciously and at the lowest dose and shortest duration possible. Cisatracurium is the preferred agent, if available, due to favorable pharmacokinetics and a decreased risk of myopathy.[6]

Prone Positioning. Prone position ventilation benefits patients with moderate to severe ARDS and confers a significant mortality benefit in the appropriately utilized patient population.[7] The mechanisms by which proning improves oxygenation are multifactorial and include improved ventilation-perfusion matching via recruitment of dependent lung tissue and facilitating secretion drainage.[5] Consider proning in patients requiring F_{IO_2} >60% who have a P_{AO_2}/F_{IO_2} ratio of <150 mm Hg despite 12 to 24 hours of optimization on the ventilator.[7] Proning is associated with significant risks including:

- ETT dislodgement.
- Pressure injuries.
- Arrhythmias.
- Hemodynamic instability.

Contraindications include:

- Spinal instability.
- Elevated intracranial pressure (ICP).
- Multiple unstable extremity fractures.
- Tracheal surgery or sternotomy within 2 weeks.

Follow a standardized proning protocol with trained personnel available to minimize the risk of complications. After placing the patient in the prone position, reassess oxygenation, and if it is improved, the patient may remain prone for 16 to 18 hours per day. Continue this intervention for up to 28 days if the patient's supine P_{AO_2}/F_{IO_2} ratio remains <150 and the patient continues to improve in the prone position.

Airway Pressure Release Ventilation. APRV maintains a high airway pressure with timed pressure releases that augment ventilation. This mimics a time-triggered, time-cycled, and pressure-targeted mode of ventilation with an inversed ratio (conventional ventilation traditionally uses inspiration and

expiration times at a ratio of 1:2 to 1:4; inverse ratio ventilation will have a ratio of 1:1 or greater) to maximize mean airway pressure and improve oxygenation. Generally, the time at higher airway pressure (T High) is 5 to 7.5 seconds, and the release time (T Low) is much shorter at 0.2 to 0.8 seconds. APRV is meant to be a spontaneous ventilation mode; the patient must be breathing spontaneously to augment the ventilation provided by the intermittent releases.

Most evidence for the advantages of APRV demonstrated improvements in oxygenation and respiratory mechanics but no mortality benefit.[8] Theoretical advantages include lung recruitment, reduced ventilator-induced lung injury, and decreased requirement for sedation and paralysis.

Disadvantages associated with APRV include the risk for auto-PEEP (especially in patients with obstructive lung disease) and hemodynamic instability secondary to high mean airway pressures. Furthermore, while using APRV, there is no direct control over TV, which can result in inappropriately high or low TVs as the patient's respiratory mechanics change. Although there is not sufficient evidence to recommend APRV for routine management of severe ARDS, it is a reasonable adjunct to treat refractory hypoxemia when other measures are ineffective.

Note: Experienced intensivists should perform APRV.

Inhaled Pulmonary Vasodilators. Inhaled pulmonary vasodilators can improve oxygenation by selectively inducing pulmonary vasodilation in well-ventilated lung units, thereby improving ventilation-perfusion matching. Inhaled vasodilators may also be useful for right ventricular dysfunction secondary to severe ARDS or pulmonary hypertension, as the associated dilation of the pulmonary vasculature reduces the afterload on the right ventricle (RV), which can improve RV function.

The most common vasodilators are inhaled nitric oxide (iNO) and inhaled epoprostenol (iEPO). Despite the associated physiological benefits described above, there has not been an

established mortality benefit associated with inhaled vasodilator therapy in ARDS patients.[9] Potential disadvantages associated with vasodilator therapy include:

- Methemoglobinemia.
- Renal impairment associated with iNO.
- Concern for platelet dysfunction with iEPO.

Direct comparisons of the efficacy of iEPO and iNO have been equivocal.[10] Despite equivocal efficacy, iEPO is less costly and easier to deliver to the patient via a nebulizer connected to the ventilator circuit.

Note: Although inhaled vasodilator therapy is an effective temporizing measure for improving oxygenation in patients with refractory hypoxemia, the feasibility of delivering these medications in a PC environment would likely be limited by logistical constraints.

Veno-Venous Extracorporeal Membrane Oxygenation. Patients with severe ARDS who experience refractory hypoxemia that does not respond to the rescue therapies above may be candidates for veno-venous extracorporeal membrane oxygenation (V-V ECMO) to provide time for lung recovery or transplantation. Consensus recommendations for the indications and contraindications for ECMO need clarification, and recommendations currently vary based on institutional experience and preference. Potential candidates include patients with a Pao_2/Fio_2 ratio <80 for 6 hours or <50 for 3 hours, refractory hypercapnia pH <7.25, and $Paco_2$ >60 for 6 hours despite optimum ventilator management. Potential contraindications include multisystem organ failure, evidence of severe or irreversible neurological injury, and the need for invasive mechanical ventilation before referral for 7 days or more. In a deployed setting, if a potential ECMO candidate is identified, prompt referral to a tertiary setting is necessary because superior outcomes have been demonstrated when ECMO is instituted early after disease onset.[11]

Management of Refractory Hypercapnia

Permissive hypercapnia (pH goal >7.20) is pivotal in managing severe ARDS to facilitate low TV lung-protective ventilation. Although permissive hypercapnia is generally well tolerated in mechanically ventilated patients, considerations for avoiding it include patients with:

- Acute cerebral disease (elevated ICP, edema, and mass lesions).
- Pronounced hemodynamic instability.
- Uncorrected hypovolemia or hemorrhage.

In mechanically ventilated patients, CO_2 clearance is mediated by increasing the RR and TV. Ideally, to minimize ventilator-induced lung injury, the RR should remain below 35 breaths per minute with a TV of 4 to 6 mL/kg, utilizing the patient's IBW. Management strategies for patients who experience refractory hypercapnia, despite maximally tolerated lung-protective ventilator settings, are discussed below.

Correct Ventilator Dyssynchrony. Ventilator dyssynchrony occurs when ventilator gas delivery and the patient's respiratory mechanics are not matched. Adverse effects associated with ventilator dyssynchrony include[12]:

- Worsening of pulmonary gas exchange.
- Impaired sleep quantity or quality.
- Delirium.
- Increased requirement for sedation or NMB.
- Increased mortality.

When ventilator dyssynchrony is encountered in the setting of refractory hypercapnia, evaluate the patient for uncontrolled pain and/or anxiety that may improve with analgesics or sedatives. In an unstable hypercapnic patient, consider deep sedation and NMB if other interventions fail to result in improvement. Furthermore, investigate the ventilator for evidence of ventilator-specific factors such as issues with triggering, breath stacking, cycling, and/or flow that require adjustment.

Bicarbonate Infusion. Treating respiratory acidemia secondary to refractory hypercapnia with intravenous bicarbonate is controversial. In the ARDSNet trial, the protocolized use of intravenous bicarbonate to maintain pH goals was allowed.[4] Currently, the evidence does not support the administration of bicarbonate. There are potential concerns, such as increased production of CO_2, resulting in worsening acidemia.

Note: Use bicarbonate cautiously in a PC setting. It would be most appropriate as a temporizing measure until definitive therapy, such as ventilator optimization or ECMO, can be initiated.

Veno-Venous Extracorporeal Membrane Oxygenation. In addition to supporting oxygenation, as discussed above, V-V ECMO can be used to stabilize patients experiencing refractory hypercapnia, allowing for the maintenance of lung-protective ventilation until clinical improvement or transplantation.

Approaches to Troubleshooting: Resistance and Compliance

The two primary variables that affect airway pressure during mechanical ventilation are resistance and compliance. When airway pressure increases or decreases above or below preset thresholds during mechanical ventilation, it manifests as an alarm and/or clinical deterioration for the patient. The ability to troubleshoot, identify, and differentiate the etiology of airway pressure alarms is an essential skill required of all intensivists.

Assess Pulmonary Mechanics

- *Inspiratory pause: Pplat.* This is performed on the ventilator by triggering an end-inspiratory breath hold for 0.5 to 2 seconds, which allows for pressure equilibration and estimation of alveolar pressure. It cannot be done if the ventilator is set in a pressure-dependent mode.
- *Expiratory pause: Auto-PEEP.* Auto-PEEP is measured by performing an end-expiratory pause for 0.5 to 2 seconds, and the pressure that exceeds the set PEEP on the ventilator is referred to as auto-PEEP.

Ventilator Alarms

High Peak Pressure, Normal Pplat: Think Resistance. When the ventilator detects disproportionately high peak pressures relative to the Pplat (Ppeak – Pplat ≥ 10 cm H_2O) in a volume-targeted mode, this typically indicates increased airway resistance for which the ventilator is compensating by increasing pressure to deliver the desired TV. Conversely, increased resistance in a pressure-cycled mode results in decreased TVs. Common causes of high peak pressure alarms in the setting of a normal Pplat include:

- ETT obstruction (eg, mucus plug, biting).
- Ventilator circuit obstruction (eg, clogged filter, kinked tubing, accumulated fluid in vent circuit).
- Bronchospasm (eg, asthma, chronic obstructive pulmonary disease).
- Ventilator dyssynchrony.

High Peak Pressure, High Pplat: **Think Compliance.** Combined high peak and Pplat pressures (Ppeak – Pplat < 10 cm H_2O) suggest an issue with pulmonary compliance. Decreased pulmonary compliance results in the ventilator requiring excessive airway pressure to deliver the desired TV. Common causes of high peak pressure alarms in the setting of an elevated Pplat include:

- Mainstem intubation.
- ARDS.
- Pulmonary edema.
- Auto-PEEP or breath stacking.
- Pneumothorax.
- Abdominal distension or compartment syndrome.
- Burn injury to the chest wall.
- Obesity.

Troubleshooting the Ventilator

Apply a structured approach to troubleshooting the ventilator when a patient experiences clinical deterioration during mechanical ventilation to identify and correct potentially life-threatening complications rapidly. The DOPES and DOTTS

mnemonics are helpful for concurrent recognition and resolution of the most common causes of acute deterioration during mechanical ventilation.

- **DOPES**
  - **D**isplaced ETT or cuff issue.
  - **O**bstruction of ETT.
  - **P**neumothorax.
  - **E**quipment malfunction (eg, accidental ventilator disconnection and incorrect ventilator settings).
  - **S**tacking (breath stacking or auto-PEEP).
- **DOTTS**
  - **D**isconnect. This can assist with evaluating the presence of breath stacking or auto-PEEP. After disconnecting the ventilator, listen for evidence of a hissing sound. If present, consider light anterior chest pressure to facilitate air release.
  - **O**xygen. Use 100% F_{IO_2} attached to a bag-valve-mask and a PEEP valve (with setting at the prior level of PEEP), evaluate chest rise, and listen for a cuff leak.
  - **T**ube position and function. Evaluate the ETT position and compare it with the depth recorded at the time of insertion. Pass a suction catheter through the ETT to evaluate for obstruction.
  - **T**weak the ventilator. Evaluate for ventilator dyssynchrony and auto-PEEP.
    - If there is evidence of auto-PEEP, consider decreasing the RR, TV, and inspiratory time.
    - For auto-PEEP causing hemodynamic instability, consider briefly disconnecting the ventilator; if using this emergency maneuver, consider the consequences of de-recruitment.
  - **S**onogram. Assess for the absence of lung sliding to suggest either a pneumothorax or mainstem intubation.

Sedation and Analgesia for Mechanically Ventilated Patients

When planning mechanical ventilation for a critically ill patient, create a sedation and analgesia plan. While, historically, deep levels of sedation have been used, current practice has shifted to minimizing sedation and emphasizing comfortable wakefulness.

Balance sedation and analgesic needs between undersedation and oversedation. Undersedation can result in the following:

- Pain.
- Anxiety.
- Fear.
- Inadvertent removal of catheters and tubes.

Oversedation can lead to:

- Hemodynamic instability.
- Increased duration of mechanical ventilation.
- Increased intensive care unit (ICU) and hospital length of stay.
- Consumption of limited resources (pumps, medications, intravenous (IV) tubing).

In an ideal situation, the patient is calm, comfortable, and able to participate in a neurologic exam. At the same time, the risk of inadvertent removal of necessary catheters and lines and the side effects of sedating medications are minimized. To achieve this goal, consider the desired level of sedation for a particular patient, methods to address the cause of increased sedation needs, and the risks and benefits of specific medications for that patient.

Standardized pain and agitation tools are crucial for defining the level of sedation a patient requires.[13] Aside from the very awake mechanically ventilated patient who may be able to communicate by writing, most of these tools rely on nonverbal cues. The Critical Care Pain Observation Tool (CPOT) scoring system (Table 6-2) is recommended to assess for pain; patients receive a score between 0 and 2 when looking for signs of discomfort based on facial expression, body movements, ventilator compliance, and muscle tension. The target score is <3 out of a maximum score of 8. The Richmond Agitation-Sedation Scale (RASS) scoring system (Table 6-3) assesses for agitation, with a score ranging from -5 for a comatose patient to +4 for a patient who is extremely agitated and posing a danger to themselves. The target score is -2 to 0. While other scoring systems exist, using these systems is recommended for simplicity.

Certain clinical circumstances may require higher degrees of sedation than the goal ranges above. For example:

- Patients with elevated ICPs may require additional sedation to reduce cerebral metabolic rate and minimize episodes of acute ICP elevation.
- Patients with severe ARDS may require deeper sedation to facilitate ventilator synchrony or to allow for the use of paralytics, as described in previous sections.
- Many patients with trauma-related causes of critical illness may have concomitant injuries such as burns, amputations, and fractures that require high doses of analgesics, but their overall CPOT and RASS scoring goals are unchanged.

In any patient with increasing sedation needs or for whom standard dosing ranges do not seem effective, consider the potential causes of increased agitation. First, rule out or treat life-threatening causes of agitation. Life threats include:

- Hypoxia.
- Hypercarbia.
- Acidosis.
- Hypoglycemia.
- Sepsis.
- Myocardial ischemia.
- Mesenteric ischemia.
- Cerebral ischemia.
- Tension pneumothorax.

The patient then should be evaluated for causes such as:

- Pain.
- Fear.
- Nausea.
- Delirium.
- Sleep cycle disturbances.
- Paradoxical drug reactions or side effects (eg, anticholinergic medications, benzodiazepines, ketamine).
- Ventilator dyssynchrony.
- Underlying psychiatric comorbidities.

Note: Always treat pain before increasing sedation.

Table 6-2. Critical Care Pain Observation Tool (CPOT) for Intubated Patients

Indicator	Description	Score
Facial expression	Relaxed, neutral	0
	Tense: presence of frowning, brow lowering, orbit tightening, and levator contraction	1
	Grimacing: the above plus eyelid tightly closed	2
Body movements	Absence of movements	0
	Protection: slow, cautious movements, touching or rubbing painful sites, seeking attention through movements	1
	Restlessness: pulling at tubes/lines/drains, attempting to sit up, thrashing, not following commands, striking at staff	2
Ventilator compliance	Tolerating ventilator	0
	Coughing, but tolerating	1
	Fighting ventilator	2
Muscle tension: evaluated by passive flexion/extension of upper extremities	Relaxed: no resistance to passive movements	0
	Tense, rigid: resistance to passive movements	1
	Very tense or rigid: strong resistance to passive movements, unable to complete	2

Reproduced from Gélinas C, Fillion L, Puntillo KA, Viens C, Fortier M. Validation of the Critical-Care Pain Observation Tool in adult patients. *Am J Crit Care.* 2006;15(4):420-427. Table 1. ©2006 American Association of Critical-Care Nurses. Used with permission. http://ajcc.aacnjournals.org/content/15/4/420.short

While treating some of these conditions may involve adding more sedating medications or increasing doses, treating others may require decreasing or eliminating medications. For patients requiring sedation outside the recommended ranges, seek expert consultation after evaluating for life-threatening causes.

Table 6-3. Richmond Agitation-Sedation Scale

Score	Summary	Description
+4	Combative	Combative, violent, immediate danger to staff
+3	Very agitated	Pulls or removes tubes or catheters; aggressive
+2	Agitated	Frequent non-purposeful movement, dyssynchronous with ventilator
+1	Restless	Anxious, apprehensive; movements are not aggressive or vigorous
0	Alert and calm	Spontaneous attention given to caregiver
-1	Drowsy	Not fully alert, but sustained awakening to voice (eye contact >10 s)
-2	Light sedation	Briefly awakens to voice (eye contact <10 s)
-3	Moderate sedation	Movement or eye opening to voice without eye contact
-4	Deep sedation	No response to voice, but movement or eye-opening to painful stimulation
-5	Unarousable	No response to voice or physical stimulation

Medication Options

Medication options for sedation and analgesia can be subdivided into background medications, medications for breakthrough agitation and pain, and drug infusions.

Background and Breakthrough Medications. Use background medications to control pain and prevent or manage delirium and agitation. Use the following guidance and dosage recommendations (Table 6-4) to plan medication administration for each patient:

- If available, place all patients requiring analgesia on scheduled acetaminophen unless there is a concern for hepatic failure or allergy.

Table 6-4. Background and Breakthrough Medications

Medication	Dose	Route	Indication	Adverse effects
Acetaminophen	1000 mg q6-8h	PO/OGT/NGT/IV	Pain, fever	Risk of hepatic toxicity in overdose
Gabapentin	300 mg qhs	PO/OGT/NGT	Neuropathic pain	Sedation/confusion; dose can be increased q3d to max 1200 mg TID
Ibuprofen	800 mg q8h	PO/OGT/NGT	Pain, fever	Renal dysfunction, GI bleeding; limit to 5 d
Ketorolac	30 mg q6h	IV/IM	Pain	Renal dysfunction, GI bleeding; limit to 5 d
Oxycodone	5-15 mg q4-6h; scheduled or prn	PO/OGT/NGT	Pain	Sedation, respiratory depression, constipation/ileus, nausea
Morphine	10-30 mg q4h scheduled or prn	PO/OGT/NGT[a]	Pain	Sedation, respiratory depression, constipation/ileus, nausea, histamine release[b]
Fentanyl	25-100 mcg q1-2h prn	IV[a]	Pain	Sedation, respiratory depression, constipation/ileus, nausea

(**Table 6-4** *continues*)

Table 6-4 *continued*

Medication	Dose	Route	Indication	Adverse effects
Hydromorphone	0.2-2.0 mg q2-4h prn	IV[a]	Pain	Sedation, respiratory depression, constipation/ileus, nausea[b]
Melatonin	3 mg qhs	PO/OGT/NGT	Sleep cycle regulation	Fatigue
Ramelteon	8 mg qhs	PO/OGT/NGT	Sleep cycle regulation	Fatigue

Abbreviations: GI, gastrointestinal; IM, intramuscular; IV, intravascular; NGT, nasogastric tube; OGT, orogastric tube; PO, per os; q, each; qhs, each bedtime; TID, three times per day.

[a] Alternative dosing routes are available, but not equivalent, and should not be used at the dosing ranges described here.

[b] Reduce doses in renal and hepatic failure.

- Gabapentin may be advantageous for patients with neuropathic pain, such as amputees.
- Consider nonsteroidal anti-inflammatory drugs (NSAIDs), but with the benefits weighed against the risk of renal dysfunction, platelet dysfunction, and gastrointestinal (GI) bleeding, especially in the setting of limited or no capability to perform endoscopy and renal replacement therapy if known side effects occur. NSAIDs may not be appropriate for most mechanically ventilated patients.
- For patients with significant pain requiring opioids, administer oral oxycodone (preferred) or morphine (less preferred) tablets or solutions, if available, as follows:
  - Use scheduled doses in patients with high background pain needs or during weaning from an opioid infusion.
  - Use as-needed dosing for patients with minimal opioid requirements.
- IV opioids can be used for supplemental analgesia in patients with high requirements. However, using a scheduled enteral multimodal pain regimen and/or peripheral nerve blocks can achieve pain goals while helping conserve parenteral medications in the resource-limited setting.[14]
- In patients with psychiatric comorbidities, restart selective serotonin reuptake inhibitors and serotonin and norepinephrine reuptake inhibitors in most circumstances, if feasible.
- Medications such as ramelteon and melatonin can be used as sleep aids to prevent delirium.[15]
- Atypical antipsychotics and clonidine may be used to treat agitated delirium or in difficult-to-sedate patients, but only after expert consultation.[16]

Infusion Medications. Sedating medications commonly used for infusion include ketamine, propofol, fentanyl, and dexmedetomidine. Less commonly used medications include midazolam, barbiturates, and morphine. For simplicity, use a single agent for sedation with as-needed doses of additional medications for most patients.

Note: Patients with high sedation needs may require infusions of multiple sedating medications; seek expert consultation in these cases.

Ketamine. Ketamine is an N-methyl-D-aspartic acid (NMDA) antagonist that produces a state of dissociative amnesia progressing to unconsciousness at higher doses while also producing analgesia through anti-nociception. Ketamine is a popular agent because of its ability to produce both sedation and analgesia, its relative ability to maintain airway tone and respiratory function, its bronchodilatory properties, and its relative hemodynamic stability. As ketamine's hemodynamic stability is attributed to the stimulation of noradrenergic neurons and inhibition of catecholamine uptake, use it with caution in patients in extremis who are likely catecholamine-deplete. Ketamine is a direct myocardial depressant and, like all sedating agents, should be used with extreme caution and in small doses in any hemodynamically unstable patient. Common side effects of ketamine include the following:

- Nausea.
- Vomiting.
- Sialorrhea.
- Psychotomimetic effects such as dysphoria, hallucinations, and nightmares.

For analgesia, ketamine doses range from 2 to 10 mcg/kg/min, while doses up to 30 mcg/kg/min may be appropriate for sedation. If ketamine is given as intermittent boluses, an hourly dose of 0.3 to 0.5 mg/kg is appropriate.

Note: Consider ketamine as a first-line agent in mechanically ventilated patients with traumatic injuries, particularly those with amputations.

Propofol. Propofol is a gamma-aminobutyric acid (GABA) agonist that produces sedation and, ultimately, unconsciousness and apnea with increasing doses. It has no analgesic properties. Peripheral vasodilation reduces blood pressure, with larger reductions occurring with bolus dosing and higher doses. Beneficial effects include decreased ICP via decreased cerebral metabolic rate, a decreased incidence of seizures, and reduced airway reactivity. The use of high doses over long durations

(>48 h and >4 mg/kg/h) is discouraged due to the risk of propofol-related infusion syndrome, characterized by:

- Lactic acidosis.
- Rhabdomyolysis.
- Myocardial dysfunction.
- Renal dysfunction.
- Hepatic dysfunction.

An appropriate dosing range is 10 to 50 mcg/kg/min.

Note: Propofol is recommended as a first-line agent in mechanically ventilated patients with increased ICP or traumatic brain injury (TBI) without other traumatic injuries.

Fentanyl. Fentanyl is a synthetic opioid and potent analgesic. At higher doses, opioids produce sedation. Like all opioids, fentanyl can cause respiratory depression, nausea, vomiting, constipation, ileus, and pruritus. With sustained use, patients may develop a tolerance, requiring increasing doses to achieve the same level of pain control. Fentanyl is not associated with histamine release and does not directly affect the cardiovascular system. In the patient in extremis; however, any decrease in sympathetic tone indirectly caused by pain relief from any analgesic can worsen the hemodynamics. Fentanyl is commonly used in combination with other sedating infusions but may be used as a sole agent depending on the patient's needs. The initial goal should be bolus doses for pain control, escalating to infusion if pain goals are not being achieved despite using a multimodal regimen (including the enteral medications described above and regional anesthesia if appropriate). Appropriate dosing for infusions ranges from 50 to 300 mcg/h. Other opioids that can be given as an infusion include hydromorphone, remifentanil, and sufentanil; obtain expert consultation before using these infusions.

Dexmedetomidine. Dexmedetomidine is an alpha-2 agonist that produces mild-moderate sedation, anxiolysis, and mild analgesia without respiratory depression. Its main advantage is minimizing requirements for opioids and other sedating

infusions. It may also be beneficial for treating poor sleep and reducing delirium. Disadvantages include bradycardia and hypotension, though hypertension and tachycardia may be briefly seen following bolus dosing. Dosing ranges for dexmedetomidine infusions are from 0.2 to 1.5 mcg/kg/h. In mechanically ventilated patients, dexmedetomidine is best used in patients with minimal sedation requirements or as a supplementary infusion to other agents.

Midazolam. Midazolam is a benzodiazepine, a class of medications that work indirectly at the GABA receptor to increase chloride channel reopening and cause neuronal hyperpolarization. Like other benzodiazepines, midazolam produces anxiolysis, hypnosis, and increasing sedation with increasing doses. Particularly when co-administered with other sedating agents and in high doses, midazolam causes respiratory depression. Midazolam has no analgesic properties. While it can be used as an infusion, significant considerations include a longer duration of mechanical ventilation and ICU stay and a prolonged duration of action after discontinuing the infusion (potentially days), particularly in patients with renal and hepatic dysfunction. As a second-line agent, it may benefit patients with high seizure risk or elevated ICP. Infusion doses are 0.02 to 0.1 mg/kg/h.

Barbiturates. Barbiturates are GABA agonists with dose-dependent sedative and hypnotic properties but no analgesic properties. The most common agents include phenobarbital, pentobarbital, and sodium thiopental, though they are not widely available and are not first-line agents due to their prolonged duration of action. These agents are most advantageous in patients with increased ICP, refractory status epilepticus, and alcohol withdrawal syndromes, as barbiturates are the most effective sedative-hypnotic agents at reducing cerebral metabolic rate relative to cerebral blood flow. Barbiturates should primarily be used as second-line agents in these populations alone or when no alternative first-line agents are available.

Morphine. Morphine is an opioid with significant associated histamine release, which can cause clinically significant hypotension. Morphine also has active metabolites that

accumulate in renal and hepatic dysfunction. Due to its longer action, active metabolites, and side effects related to histamine release, morphine is not a first-choice agent for sedation in mechanically ventilated patients. It can be given by bolus dosing, as Table 6-3 describes. Limit infusions to palliative care or when no other agent is available. Dose ranges for infusions are 1 to 10 mg/h. Adjust the dose based on the degree of respiratory depression.

Sedation for Mechanically Ventilated Patients with Traumatic Brain Injury

Sedation for mechanically ventilated patients with a TBI has been controversial. Goals in brain-injured patients focus on preventing secondary injury by maximizing cerebral oxygen delivery and minimizing cerebral oxygen demand. The ideal sedating agent would reduce cerebral metabolic rate, maintain cerebral perfusion pressure by maintaining mean arterial pressures and cerebral autoregulation, and reduce, or at least not raise, ICP. Additional ideal properties include anti-epileptic activity and a rapid offset to facilitate neurologic exams.[17,18] Ketamine traditionally was contraindicated in this patient population due to early reports demonstrating increased ICP with ketamine sedation. However, recent studies employing controlled ventilation with normocarbia have demonstrated that ketamine has a minimal impact on ICP (neither increased nor decreased), with some studies suggesting it may decrease ICP and be neuroprotective, including having anti-seizure properties.[19,20] In the polytrauma patient with additional injuries, ketamine sedation provides analgesia and relative hemodynamic stability compared with other IV sedation agents.

The mechanism by which ketamine induces sedation is fundamentally different from that of GABA-ergic sedating agents such as propofol, benzodiazepines, barbiturates, and inhaled anesthetics. While these agents are associated with varying degrees of reduced cerebral metabolic rate relative to cerebral blood flow, ketamine may maintain or even increase cerebral metabolic rate, an effect that is potentially harmful to the injured brain. Assuming mean arterial pressure is maintained,

the theoretically beneficial effects of these other GABA-ergic agents make them first-line agents for the brain-injured patient, particularly when the brain injury is the primary or only injury. However, the evidence for any particular sedating agent over any other is limited, with the data regarding ketamine in TBI being so scarce that the Brain Trauma Foundation guidelines do not even include it as a recommended agent.[21] The decision to use ketamine instead of another IV sedating agent in the brain-injured patient should factor in the severity of the brain injury relative to other injuries, the patient's hemodynamic tolerance of different sedation regimens, and the availability of resources.

Medication During Transport of Mechanically Ventilated Patients

Special consideration should be given to mechanically ventilated patients requiring transport. During transport, space and resource limitations may make replacing any inadvertently removed catheters or lines difficult, if not impossible. Deeper levels of sedation may be required. In patients requiring multiple life-saving interventions or who are very unstable, consider using paralytics to further decrease the risk of accidental catheter or line removal. Before administering a paralytic, a level of deep sedation (RASS -5) should be achieved and maintained to reduce the potentially significant psychiatric complications of experiencing paralysis while undersedated. A paralytic may also make mechanical ventilation easier due to improved chest wall compliance. Appropriate agents include rocuronium (0.6 mg/kg IBW bolus, followed by 0.4-1.0 mg/kg/h), vecuronium (0.1 mg/kg IBW bolus, followed by 1 mcg/kg/min), or cisatricurium (1-3 mcg/kg/min infusion).

In conclusion, provide sedation and analgesia to mechanically ventilated patients to minimize pain, fear, and anxiety, and to prevent the inadvertent removal of life-saving interventions. Use background medications to decrease the need for sedating infusions. Target the infusion to the specific needs of the patient, with ketamine being an appropriate first choice for the majority of traumatically injured patients. Target any infusion and bolus drug administration to CPOT and RASS scores to minimize the risks of oversedation by using the lowest reasonable doses. Seek expert consultation for the difficult-to-sedate patient.

Transport of the Mechanically Ventilated Patient

Despite the best capabilities and resources, the care of patients in a PC environment inevitably requires patient transport to a higher level of care. Highly trained personnel with specialized equipment are required to ensure high-quality and safe patient care throughout the transport. When moving a critically ill patient on a mechanical ventilator, the requirement for transport becomes more risk laden and complicated due to the numerous aspects of the transport environment, equipment and medication requirements, and logistical considerations. Ventilator management in transport is resource intensive. Ideally, transporting a critically ill patient on a mechanical ventilator should be well planned and aim to maintain the same or higher level of care during transport compared to pretransport.

A static care environment is physically different from a transport care environment, which may require provisions for noise, low light, changes in humidity and pressures, and limited space. Movement and vibration can cause disruption, patient distress, and alarms. Resources, equipment, and supplies may be more limited in quantity and functional capacity during the transport process compared with a static environment. Equipment like a transport mechanical ventilator is usually more basic but has undergone strict testing to ensure that it can withstand the rigors of transport. Notably, the transport environment is significantly limited by the access, resources, and capability to address en-route emergencies. The mode of transport, ground vs. air, involves additional considerations for the transport of a mechanically ventilated patient. Awareness of the en-route care environment's effect is essential for safe transport (Table 6-5).

Clinical preparation for transporting a mechanically ventilated patient should include assessing stability and mitigating risks associated with transport. The ultimate decision to transport a patient on a mechanical ventilator is determined by the patient's clinical condition, the sending facility's capabilities to keep the patient, the transport team, and the logistical components of transport. Detailed pretransport evaluation of these patients is essential to ensure that they are stable enough to endure the stressors and duration of transport. If possible, transition patients

Table 6-5. Challenges, Conditions, and Solutions When Transporting a Mechanically Ventilated Patient by Ground and Air

Challenges in transport	Considerations
Migration or dislodgement of breathing tube	1. Ensure adequate sedation 2. Check depth of ETT 3. Check cuff pressure (altitude) 4. Secure breathing tube with device or tape 5. Physically secure airway device during bed transfer 6. Anticipate patient agitation, especially during takeoff, landing, turbulence, bumpy roads, etc
Mobilization of respiratory secretions	Maintain dedicated suction for upper and lower respiratory tract
Drying of respiratory secretions in air transport	1. Use heat and moisture exchanger 2. Periodic suctioning may be needed to prevent mucous plugging
Hypoxemia during transport, especially at altitude	1. Ensure appropriate oxygen calculations for duration of transport 2. Anticipate increased need for PEEP and/or F_{IO_2} when flying at altitude 3. Caution against fixed-wing (>8000 ft) or long range ground transport when PEEP >14 cm H_2O and/or F_{IO_2} >70%

Abbreviations: ETT, entotracheal tube; PEEP, positive end-expiratory pressure.
Adapted from Cannon J, Pamplin J, Zonies D, et al. Acute Respiratory Failure. Joint Trauma System Clinical Practice Guidelines website. Published January 23, 2017. Accessed November 30, 2022. https://jts.health.mil/assets/docs/cpgs/acute_respiratory_failure_23_january_2017_id06.pdf

to the transport ventilator for a set period before transport to ensure appropriate oxygenation and ventilation while on the transport ventilator settings. Set alarms to parameters that alert the team to equipment issues or changes in patient status without causing frequent false alerts that distract the transport team.

Exhibit 6-1 Pretransport Checklist

Place patient on gurney or litter with litter pad and straps; use backrest as needed.

Verify appropriate IV access with at least two peripheral IVs or a double-lumen central line.

Consider need for intubation before transport, especially if Glasgow Coma Scale <9, burn patient with potential airway involvement, or patient is at risk for pulmonary compromise during flight.

Preposition bag-valve-mask (BVM) attached to oxygen source near patient's head, especially if intubated.

Place and appropriately position cardiac monitor, pulse oximeter, noninvasive blood pressure, and other monitors (as needed) for safe and continuous monitoring.

Review alarm settings to optimize safe monitoring.

Confirm removal of all microbubbles from pressure monitoring lines.

Provide gastric decompression (nasogastric or orogastric tube) and venting colostomy bags.

Secure all equipment (tubes, IV lines, drainage devices).

Remove all air from IV bags and place free-flowing bags in pressure bags.

Obtain pre-transport blood gas (if available) while on transport ventilator; adjust ventilator settings as indicated.

Complete a neurologic examination (if able) for patients at risk for neurologic compromise.

Evaluate and record sedation levels in ventilated patients.

Administer pain medications as indicated.

Provide hearing and eye protection for patient and inform the patient when you place it.

Prevent heat loss by ensuring appropriate blankets for the patient's entire body.

Take appropriate spinal precautions unless the patient has been medically cleared for a spinal injury.

Adapted from Walrath BD, et al. Interfacility Transport of Patients Between Theater Medical Treatment Facilities (CG ID: 27). Joint Trauma System website. Published April 24, 2018. Accessed December 21, 2022. https://jts.health.mil/assets/docs/cpgs/Interfacility_Transport_of_Patients_between_Theater_Medical_Treatment_Facilities_24_Apr_2018_ID27.pdf

Generally, lung-protective ventilation with a goal TV of 6 mL/kg IBW is the appropriate target for transport settings. Anticipate a decrease in the patient's oxygenation during flight due to increased ambient pressure. Give careful consideration to flight safety for patients who are on or near maximal ventilator settings, which can be defined as a F_{IO_2} >70% and/or a PEEP ≥14 cm H_2O, as there is little room to adjust the settings safely if a patient worsens.

There are numerous actions required to prepare a mechanically ventilated patient for transportation. Follow the checklist in Exhibit 6-1.

Ensure adequate supplemental oxygen before transport to provide full support throughout transport. Perform supplemental oxygen requirement calculations before transport with knowledge regarding the mode of oxygen delivery. Include the possibility of increased oxygen requirements, adjustments in travel plans, or increased transport time. Ideally, each mechanically ventilated patient should have a dedicated portable therapeutic liquid oxygen system. Periodically compare actual oxygen consumption with the predicted consumption rate during transport to ensure the timely discovery of excess consumption.

Critically ill patients on mechanical ventilation require ongoing management during transport, which involves close monitoring of the patient's hemodynamics with appropriate adjustment of ventilator settings. Continuous cardiac monitoring, pulse oximetry, and $Etco_2$ are recommended methods for monitoring. While blood gas analysis is not required, this capability is recommended to assess for changes during long transports. Additionally, pay attention to the ETT cuff pressure, appropriate airway suctioning frequency, mouth care, and elevation of the head of the transport litter.

Changes in patient status during transport, particularly oxygen desaturations, should prompt immediate interventions. The following are five fundamental steps to troubleshooting hypoxemia during transport:

1. Confirm the location of the pulse oximeter and waveform (if available).

2. Confirm the position of the ETT by looking at its location relative to pretransport, evaluating chest wall expansion and $Etco_2$, and verifying appropriate TVs and associated pressures.
3. Attempt manual bag ventilation with an attached PEEP valve.
4. Suction the airway to exclude mucous plugging.
5. Evaluate chest tubes, if present, for proper location and functional suction.

Special Considerations in Prolonged Care

Many unique challenges may arise while providing mechanical ventilator support in a PC setting, including the following:

- Limited medical supplies and oxygen.
- Competing missions.
- Unforgiving temperatures.
- Threat of indirect and direct fire.
- Issues with resupply.
- Limitations in electrical supply and fuel.
- Limitations in capacity and personnel.

These restraints may drive difficult decisions regarding patient transfer to higher levels of care.

Always discuss special considerations through triage about the capability to manage an individual requiring mechanical ventilation due to the resources that this modality requires. There is often limited or no capability for high-flow nasal cannula; however, there are case reports that describe the application of noninvasive positive air pressure using a Zoll Impact 731 (Zoll Medical Corporation) portable ventilator in a resource-limited environment.[22]

The primary focus of mechanical ventilation in a resource-limited environment is oxygen conservation. Techniques to obtain the lowest level of supplemental oxygen while providing lung-protective ventilation—eg, using low TV ventilation targeting TVs of 6 mL/kg IBW—include aggressive self- and manual proning (ARMA trial[4]) and proning severe ARDS patients (PROSEVA trial[7]). To preserve oxygen, use a

high PEEP strategy to increase mean airway pressure. Use bedside Drive Pressure to regulate the degree of alveolar recruitability to achieve the lowest F_{IO_2} required. PC without the ability for renal replacement therapy or on-site ECMO has led to conservative fluid management strategies, often using albumin and loop diuretics to achieve a negative fluid balance.[23]

Oxygen Supply and Generation

The availability of a continuous oxygen supply and the ability to generate oxygen directly affect the management of individuals requiring mechanical ventilation, including ARDS. Oxygen generation is often challenging due to logistics, including continuous power and the ability to maintain these systems. Examples include the portable oxygen generation system (Figure 6-1) and expeditionary deployable oxygen concentration system

Figure 6-1. A US Army Role 3 portable oxygen generation system. Photograph courtesy of On Site Gas Systems, Inc.

(Figure 6-2). These systems are significantly affected by the environment and limitations in the logistical support required to move these heavy units.

Equipment

The Zoll Impact 731, Hamilton T1 (Hamilton Medical), Eagle Impact Univent 754 (Impact Instrumentation Inc), and SAVe II (Automedx LLC) are examples of portable ventilators often used in a resource-limited environment. These portable ventilators have no preset noninvasive mode. The Zoll Impact 731 has been used successfully with a full-face mask, but expert telemedicine support is recommended before using this mode. The pressure support mode on the Zoll Impact 731 has also been used to simulate a continuous positive airway pressure setting, which can be achieved with a set PEEP without additional pressure support. This method provides adequate mean airway pressure

Figure 6-2. An expeditionary deployable oxygen concentration system. Photograph courtesy of PCI Gases.

to achieve alveolar recruitment and enhanced airway clearance, thereby preventing endotracheal intubation.

These ventilators can deliver 100% F_{IO_2} if available and provide levels of PEEP to the lower twenties to augment oxygen delivery. The Zoll Impact 731 and Hamilton T1 can provide inverse ratio pressure-controlled ventilation, which could increase mean airway pressure to improve oxygenation and possibly preserve supplemental oxygen use. Pressure alarms are modifiable for continuous assessment of airway pressures, to include the ability to check peak inspiratory pressure and Pplat to assess for the risk of barotrauma and to optimize PEEP by calculating Drive Pressure (Drive Pressure = Pplat – PEEP with a goal of less than 15). Only the SAVE II is an exception, as this ventilator cannot calculate a Pplat.

A detailed setup guide, power checks, initial settings, and troubleshooting of these portable ventilators are included in Appendix B of the Mechanical Ventilation Basics Joint Trauma System CPG.[24] Battery life of these ventilators is highly variable with the possibility of 4 to 6 hours under peak operating conditions.

Summary

Providing mechanical ventilator support in a PC setting can be complex and challenging. Discuss triage considerations regularly in every instance due to the required resources to maintain an individual on mechanical ventilation. The primary strategy for mechanical ventilation in a resource-limited environment is oxygen conservation due to the logistical limitations of power availability and equipment maintenance. Understanding several foundational concepts of mechanical ventilation can minimize iatrogenic injury while optimizing the chances for recovery. Despite the best capabilities and resources, the care of patients in a PC setting inevitably requires patient transport to a higher level of care.

For TCCC recommendations, go to the US Army Combined Arms Center website. https://usacac.army.mil/sites/default/files/publications/17493.pdf
For Clinical Practice Guidelines, go to the Joint Trauma System website. https://jts.health.mil/assets/docs/cpgs/Airway_Management_in_Prolonged_Field_Care_01_May_2020_ID80.pdf

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Chapter 7

BURNS

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Introduction

A burn injury can be one of the most resource- and labor-consuming injuries in the prolonged care (PC) environment. Burn injuries occur in nearly 10% of all combat casualties and present a significant source of morbidity and mortality. Burns that cover over 20% of a person's body are life threatening and require specific interventions to save the patient after injury. Managing burns requires airway assessment for associated inhalation injury, accurate estimation of burn size to initiate appropriate fluid resuscitation, and early application of antimicrobial agents to prevent burn wound infection.

Key Principles

- Burn patients are trauma patients with burns. Address immediate life-threatening injuries, such as hemorrhage and airway management, first, using tactical combat casualty care (TCCC) guidelines.
- Burn patients are at much higher risk for hypothermia than other trauma patients. Take immediate measures to prevent and reverse hypothermia.
- Inhalation injury increases mortality in burn patients. Early airway management is a key treatment priority.
- Accurately determine burn size, which is paramount to planning effective post-burn care.
- Large burns require considerable fluid resuscitation for up to 48 hours after injury. Resource management and planning are essential in the PC environment.
- Prevent infection in burn wounds; this dramatically improves outcomes.

Inhalation Injury

Smoke inhalation injury occurs in approximately 20% of burn-injured patients. Burns or explosions in enclosed spaces, such as vehicles or buildings, are associated with a significantly higher risk of inhalation injury. It is very uncommon to sustain an inhalation injury in an open space.

Symptoms of smoke inhalation include hoarseness of voice, stridor, and cough. Monitor symptomatic patients closely. They often will require endotracheal intubation for airway protection. Endotracheal tubes (ETTs) used for intubation should be cuffed and secured with cotton ties or similar bindings after placement because the tape does not adequately stick to a patient's face, even if the face is not burned.

Frequent suctioning prevents ETT obstruction by secretions. It is a management priority for patients intubated due to inhalation injury. Secretions associated with inhalation injury are unique; they include casts and debris and can quickly occlude the ETT. Take the following steps to treat an intubated inhalation patent:

- Instill 3 to 5 mL of saline to facilitate suctioning.
- Use bronchodilators, if they are available, to help mobilize secretions.
- Place an orogastric or nasogastric tube to decompress the patient's stomach after intubation.
- Monitor oxygen saturation and end-tidal CO_2 to gain helpful information about ventilation status, such as a need for increased positive end-expiratory pressure (PEEP) or more frequent suctioning to relieve ETT clogging.

Burn Size

Determining the total body surface area (TBSA) of burned skin on a patient can be challenging. Once wounds have been cleaned or debrided, calculate the percent (%) TBSA of the burn. Superficial burns (also known as first-degree burns) look like a sunburn. Do not count the intact epidermis (top layer of skin) in TBSA. Second- and third-degree burns are deeper. Count the damaged epidermis and dermis in TBSA. These deeper burns can have blisters; loose dead skin; or a thick, leathery eschar.

Use the patient's hand size (including fingers) to approximate 1% TBSA for small burns. For larger burns, use the Rule of Nines to calculate burn size (Figure 7-1).

Fluid Resuscitation

Fluid resuscitation aims to replace the fluid lost in the extravascular tissues after a burn injury. This fluid loss is often most severe in the first 8 to 12 hours after injury but may last up to 48 hours. The composition of the fluid lost into tissues closely resembles common isotonic intravenous fluids, such as lactated Ringer solution and PlasmaLyte. Calculate the initial starting rate for fluid replacement

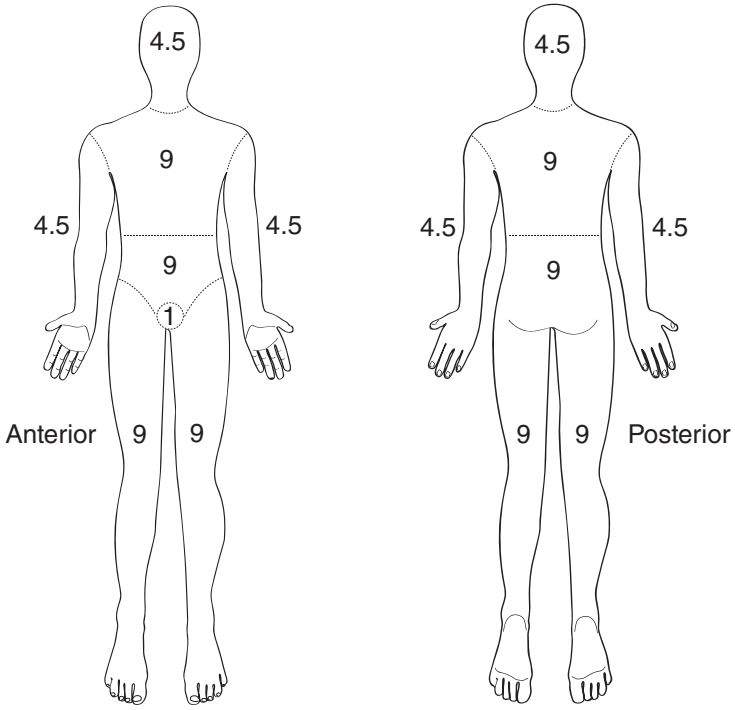

Figure 7-1. Use the Rule of Nines to determine burn size. For example, a patient with the entire anterior torso and entire right lower leg burned (second or third degree) has an 18 + 18 = 36% total body surface area burn injury.
Illustration by Borden Institute.

using the Rule of 10s. This rule states that for patients weighing 40 to 80 kg (small to average-size adults), multiply the patient's TBSA by 10. For example, a 35% TBSA burn would start at 350 mL/h.

Rule of 10s: Initial hourly rate = % TBSA burn x 10 mL/h

For patients weighing over 80 kg, add 100 mL/h for every 10 kg over 80. For example, if a patient with 35% TBSA weighs 100 kg, the initial rate would be 350 mL/h + 200 mL/h = 550 mL/h.

Table 7-1 shows common weights of service members and their initial fluid rate, assuming a 50% TBSA burn.

Table 7-1. Using the Rule of 10s, the Initial Fluid Infusion Rate Is Shown for Different Body Weights[a]

Weight in kg (approximate weight in lb)	Initial fluid rate (mL/hr)
50 kg (110 lb)	500
60 kg (130 lb)	500
70 kg (155 lb)	500
80 kg (175 lb)	500
90 kg (200 lb)	600
100 kg (220 lb)	700
110 kg (240 lb)	800
120 kg (265 lb)	900

[a] This chart is based on a 50% total body surface area burn.

Monitoring the patient after starting resuscitation is essential to adjusting the fluid rate. The gold standard for monitoring resuscitation measures hourly urine output. The hourly urine output goal for adult patients is 30 to 50 mL/h. If the urine output is too low, increase the hourly intravenous (IV) infusion rate by 25%. For a patient receiving 350 mL/h, who makes 10 mL of urine in an hour, the next hour's infusion rate should be 350 × 0.25 = 87.5 mL (rounding to 90 mL is appropriate). The new rate is 350 + 90 = 440 mL/h. If urine output cannot be monitored, other

measures may prove helpful. Assess heart rate, capillary refill, or palpable peripheral pulses (may be difficult in burned tissue with edema). Many burn patients will be very tachycardic due to the severe inflammatory response. Therefore, trending the heart rate response to fluid administration changes is more beneficial than determining the absolute heart rate value.

Patients with smaller burns and those able to consume liquids by mouth may be able to supplement their burn resuscitation using enteral resuscitation fluids. Drinking plain water can cause hyponatremia; therefore, provide electrolyte-containing solutions. The World Health Organization's oral rehydration solution contains sugar and salt and can be mixed with water. Many commercially available electrolyte solution powders are available as well. Add salt and baking soda (if available) to Gatorade (PepsiCo) to optimize its electrolyte content. See Chapter 12, Nutrition, for more information on hydration.

Fluid resuscitation is very resource intensive, regardless of the type of solution used. Continually assess the availability of fluids needed in resource-constrained environments or when resuscitating multiple casualties.

Wound Care

Preventing burn wounds from becoming infected is essential for patient survival. Within 24 hours of injury, complete these primary procedures for burn wound care:

- clean wounds with chlorhexidine;
- remove all loose, dead tissue by gently scrubbing the wounds with gauze; and
- apply an antimicrobial cream, solution, or dressing.

If chlorhexidine is not available, use a standard antimicrobial dish or hand soap. There are many choices for antimicrobial dressings, creams, and solutions, providing a wide array of antimicrobial and anti-fungal coverage.

Wound care is very resource and labor intensive. It requires careful planning to determine the supplies and personnel needed for dressing changes, which may be required daily for most

creams and solutions. Some dressings, such as silver nylon, can be left in place for up to 5 days, with only the outer dressing of gauze needing to be re-wet (with water from any source) approximately every 6 hours. Even with these dressings, it is preferable to change them every day.

Wound care can be excruciating for patients, and appropriate analgesia (see Chapter 8, Analgesia) and anti-anxiolytics (eg, lorazepam) are necessary.

There is no role for systemic antibiotics in preventing burn wound infections. If burn wounds are going to become infected, it typically occurs about 3 to 5 days after injury. Infection can manifest as cellulitis, increased pain, or a foul wound smell. If a patient's wounds are infected, immediately take the following steps:

- treat with systemic antibiotics that cover gram-positive organisms,
- debride devitalized tissue, and
- place fresh antimicrobial dressings.

If the burn wound becomes infected more than 5 days after injury, include systemic antibiotic coverage for gram-negative organisms, specifically *Pseudomonas aeruginosa*.

For infected wounds, local wound care can include using Dakin solution, which is roughly equivalent to diluted bleach and kills many types of bacteria and fungi.

> Dakin solution: Mix 32 ounces water, 1 tablespoon bleach, and 2 teaspoons baking soda. Baking soda (if available) decreases the toxicity of bleach to healthy tissue.

Switch Dakin solution to other antimicrobial solutions or dressings 48 hours after initial use to minimize the negative effect on healthy tissue.

The above procedures and steps in wound care are also effective for soft tissue injuries from other traumatic mechanisms. Remove as much gross contamination from blast-injured tissue, open fractures, and other penetrating traumatic injuries. Use Dakin solution in grossly contaminated wounds after debriding them

as much as possible. Use systemic antibiotics as appropriate for associated traumatic injuries (eg, broad coverage for contaminated wounds and extensive open fractures), understanding that they are not preventing burn wound infection.

Special Considerations

Electrical Burns

High-voltage electrical burn injury is common in the deployed environment. This type of injury is associated not only with skin burns but also with extensive muscle damage. Due to the severe nature of associated muscle injury, these patients require aggressive fluid resuscitation to clear the products of muscle damage from the kidneys. A target urine output of 70 to 100 mL/h is vital to removing damaging byproducts from the urine. Muscle damage from high-voltage electrical burns is like rhabdomyolysis from other conditions, such as crush injury. High-voltage electrical injury patients often require more immediate and extensive debridement of devitalized tissue, including muscle, than thermal burn injuries. Overall, these patients are more gravely injured than patients suffering only thermal injury.

Extremity Burns

Extremity burns pose a particular challenge. The combination of circumferential burns and tissue edema present after a burn injury can threaten limb viability. Mitigate the effect of edema as follows:

- elevate the limb above the level of the heart,
- use passive or active range of motion procedures to mobilize edema,
- avoid constrictive dressings, and
- frequently monitor peripheral pulses using a Doppler.

If pulses become diminished or absent, perform an escharotomy to restore blood flow. This procedure requires incising the layers of the burned dermis and epidermis to release the interstitial tissue pressure buildup. To control bleeding during the escharotomy, use combat gauze, electrocautery, and other hemostatic adjuncts.

Nutrition

Patients with burn injuries and extensive wounds become hypermetabolic. Without adequate nutrition, these patients can experience impaired immunity, decreased wound healing, and pneumonia. See Chapter 12, Nutrition, for more information on feeding burn patients in a PC environment.

Summary

For additional burn management guidelines, go to the Joint Trauma Systems website. https://jts.health.mil/assets/docs/cpgs/Burn_Management_PFC_13_Jan_2017_ID57.pdf |
Consults are available 24/7 at the US Army Institute of Surgical Research, Burn Center.
210-916-BURN (2876), DSN 312-429-BURN (2876), and burntrauma.consult.army@health.mil

Chapter 8

ANALGESIA

Steven G. Schauer, DO, MSCR; Andrew D. Fisher, MD, PA-C; and Michael D. April, MD, PhD

Introduction

Analgesia (pain control) is a crucial early intervention in the care of trauma patients. While administering pain medication is not lifesaving, there are long-term harmful effects of untreated or undertreated pain. Additionally, treating pain can aid in evaluating the trauma patient by improving anxiety and cooperation. The priority is keeping the patient alive. Analgesia should come shortly after lifesaving interventions such as hemorrhage control. Tailor pain medication to the patient's pain severity and current physiological state.

Key Principles

- Always prioritize lifesaving interventions first.
- The goal of analgesia is to control pain and anxiety.
- Administer pain medications as early as possible in the casualty's clinical course.
- Tailor pain medications and doses to the casualty's current physiologic state (eg, hypotensive, tachycardic).
- Titrate to effect. You can add more analgesics but cannot remove them after administration.
- Choose intravenous (IV) and intraosseous (IO) routes over intramuscular or intranasal routes.
- Ketamine, opioids, and benzodiazepines can have both synergistic effects and a higher risk of adverse events when co-administered.
- When mixing medications into crystalloids, saline is preferred, but use lactated Ringer solution or PlasmaLyte if saline is unavailable.
- Measure and document pain scores and reassessments.

Categories of Analgesia Goals

- Pain from trauma. Consider shorter-acting agents up front, quickly followed by long-acting agents to reach a steady state of tolerable pain without respiratory depression.
- Breakthrough pain (occurring after achieving a steady state). Consider titrating up the agents to achieve a steady state of tolerable pain.
- Procedural pain (resulting from medical procedures). Consider the use of short-acting agents in bolus dosing.

Monitoring

At a minimum, monitor blood pressure and heart rate. Use continuous pulse oximetry with direct line-of-sight observation for more effective monitoring. Ideally, also use continuous end-tidal CO_2 monitoring.

Oral Analgesia

Table 8-1 describes oral analgesics useful in prolonged care (PC). Oral analgesia is ideal for mild to moderate pain, especially when the casualty can continue to fight or self-administer pain medications such as oral transmucosal fentanyl citrate (OTFC) or acetaminophen and meloxicam (in the Combat Wound Medication Pack). The casualty can self-titrate when appropriate, freeing resources for other prioritized interventions.

While included in the oral analgesia section, OTFC and sublingual sufentanil are not primarily absorbed in the gastrointestinal tract after oral consumption. Instead, absorption of both drugs occurs in oral mucosal tissue. OTFC carries a Food and Drug Administration black box warning against outpatient prescribing in opioid-naïve patients. The warning does not apply to settings of continuous patient monitoring via either standard monitoring technology or direct observation by the medical operator. Repeat dosing of sublingual sufentanil and OTFC are allowable. Dose stacking results in additive effects.

Parenteral Analgesia

Parenteral (intravenous [IV], intramuscular [IM], intraosseous [IO], and intranasal [IN]) analgesia administration is best for moderate to severe pain. Table 8-2 describes parenteral analgesics useful in PC.

Parenteral medications, especially IV or IO, have the advantage of very predictable serum levels and more reliable analgesic effects than oral pain medications. Use IM only as a temporary measure until obtaining IV or IO access. IM medications have variable and delayed absorption. Absorption delays may also occur in hemorrhage, with decreased perfusion to the muscular tissue. IN is an alternative to IM administration when lacking IV access, but the absorption is variable. There is less flexibility in titrating the quantity of medication administered, as patients generally cannot tolerate IN volumes exceeding 0.5 mL in each naris.

Continuous Infusions

Continuous infusions generally alleviate severe pain that would require repeated dosing, most often in intubated patients. However, ketamine is safe in low doses in non-intubated patients. Due to the risk of respiratory depression, use fentanyl infusions for intubated patients only. In the awake patient, consider using "as needed" dose medications to reduce the amount of total drug administered and to ensure completion of repeat assessments before administration of each dose. Patients may benefit from a bolus dose before increasing the infusion rate when using continuous infusions. The bolus dose helps rapidly achieve a steady state of tolerable pain. Table 8-3 describes continuous infusion drugs useful in PC.

Regional Nerve Blocks

Only trained individuals should use regional nerve blocks. The selection of a specific block depends on the situation, but relatively distal blocks are preferable to proximal blocks. When possible, use ultrasound to identify anatomy, needle placement, and anesthetic injection. Ultrasound is not required for digital blocks. Consider less technically challenging blocks such as Bier blocks (intravenous local anesthesia) if training or background experience is limited.

Table 8-1. Oral Analgesics and Usage Guidelines for Prolonged Care

Drug	Dose	Onset	Duration	Notes
Meloxicam	15 mg	<1 h	24 h	May cause reflux, gastritis, nausea/vomiting, diarrhea
Acetaminophen	650-1000 mg	<1 h	4-6 h	Allergic reactions are rare Limit total daily dose to no more than 4000 mg
Ibuprofen	600 mg	<1 h	4-6 h	Repeated use associated with gastrointestinal ulcer and decreased kidney function May cause stomach upset
Naproxen	220 mg	30-60 min	< 12 h	Repeated use associated with gastrointestinal ulcer and decreased kidney function May cause stomach upset
Codeine	15-30 mg	<1 h	4-6 h	Constipation Respiratory depression Combine with acetaminophen
Hydrocodone	5-10 mg	<1 h	3-4 h	Constipation Respiratory depression Combine with acetaminophen
Oxycodone	2.5-10 mg	<1 h	3-6 h	Constipation Respiratory depression Combine with acetaminophen

(**Table 8-1** *Continues*)

Table 8-1 *Continued*

Drug	Dose	Onset	Duration	Notes
Sufentanil	30 mcg	10 min	1 h	Constipation Respiratory depression After 12 doses, peak plasma increases 3.7 times Steady state achieved at 7 doses
Oral transmucosal fentanyl citrate	400 or 800 mcg	10-30 min	1-2 h	Constipation Respiratory depression Tape to the casualty's thumb or to a rubber band under tension

Table 8-2. Parenteral Analgesics and Usage Guidelines for Prolonged Care

Drug	Dose	Onset	Duration	Notes
Morphine	4-8 mg	<5 min IV, 50-90 min IM	4 h	Constipation Respiratory depression
Hydromorphone	0.2-1 mg IV, 1-2 mg IM	<5 min IV, 15 min IM	3-4 h	Constipation Respiratory depression
Fentanyl	50-100 mcg IV or IM	Immediate IV, 7-15 min IM	0.5-1 h IV, 1-2 h IM	Constipation Respiratory depression Rigid chest syndrome
Ketamine	0.3-0.5 mg/kg of ideal body weight IV, IO, or IN; 0.5-0.7 mg/kg IM	<1 min IV or IO, 1-5 min IM	15-45 min IV or IO, 30-120 min IM	May still cause changes in mental status at low doses; agitation Rapid pushing may cause vocal cord spasm Vomiting may occur after the drug starts to wear off
Ketorolac	15-30 mg 30-60 min IM	1-3 min IV,	4-6 h	Repeated use associated with gastrointestinal ulcer and decreased kidney function May cause stomach upset

Abbreviations: IM, intramuscular; IN, intravenous; IO, intraosseous; IV, intravenous.

Table 8-3. Continuous Infusion Analgesics and Usage Guidelines for Prolonged Care

Drug	Dose	Onset	Notes
Ketamine	Start at 0.1 mg/kg/h and titrate up at 0.05 mg/kg/h; titrating to desired endpoint	<1 min	Bolus ketamine at standard pain doses before titrating up the continuous infusion Prolonged use may cause delirium Prolonged use may cause bladder irritation
Fentanyl	1-2 mcg/kg/h	<1 min	Bolus fentanyl at standard pain doses before titrating up the continuous infusion Prolonged infusions may result in opioid tolerance

Summary

For Prolonged Care Guidelines, go to the Joint Trauma System website. https://jts.health.mil/assets/docs/cpgs/Prolonged_Casualty_Care_Guidelines_21_Dec_2021_ID91.pdf

Chapter 9

TELEMEDICINE USE DURING PROLONGED CARE

Jeremy C. Pamplin, MD; Robert McLeroy, MD; William Vasios, APA-C, MPAS; and Christopher J. Colombo, MD

Introduction

Caregivers providing prolonged care (PC) in resource-limited, austere, and operational environments are often challenged to provide care beyond their scope of practice, training, or experience. Caregivers meet these challenges with various responses, ranging from cavalier patient care to decision paralysis. Still, most caregivers try for a reasoned and practicable approach and worry that their actions are ineffective or harmful.

Over the past several decades, telemedicine has offered military caregivers across the globe access to expertise not otherwise immediately or locally available. While there is limited evidence that providing expert consultation improves patient outcomes, experience and some evidence show that telemedicine optimizes evacuation, reduces lost duty time, saves costs (primarily due to reduced evacuation and travel time),[1-3] and improves successful completion of procedures usually at the cost of efficiency.[4-6] More recently, telemedicine has been shown during high-fidelity medical simulations to improve casualty outcomes and quality of care delivered and reduce cognitive load and subjective stress but at the expense of time.[5,7]

Clinician remote experts (REs) currently provide teleconsultation. Knowing the telemedicine capabilities available in the US Military for use during PC, the significant limitations, and the best practices helps local caregivers (LCs) working in resource-limited, austere, and operational environments (AOEs). Note that direct-to-patient telemedicine systems (eg, tele-behavioral health) are not included here because in nearly all circumstances, PC is defined by a caregiver managing a casualty beyond a desired evacuation time.

Key Principles

- LCs managing casualties during PC face complex medical and surgical challenges, usually managed by a team of specialists in a hospital. Training clinicians with all knowledge, skills, and abilities necessary to optimize casualty outcomes is impossible.
- Telemedicine is a readily available solution that provides LCs access to REs that can enhance PC by sharing their knowledge and experience. PC aided by REs through telemedicine is ***better*** than LCs providing care alone (***minimum***) but beyond their scope, experience, or comfort. It is ***best*** to evacuate casualties to the right level of care within the care continuum.
- The most significant limitation of telemedicine is time. Telemedicine takes more time than physical medicine.
- Practicing telemedicine during training is essential to test primary, alternate, contingency, and emergency (PACE) plans and become efficient in all situations.
- Scripting communication when possible is an efficient best practice to maximize information transfer.

Current State

The Advanced Virtual Support for Operational Forces (ADVISOR) program allows caregivers worldwide to call a single toll-free number to access specialty and emergency consultation as needed. While certain operationally relevant specialties are managed more closely and made available more rapidly (critical care, general or trauma surgery, infectious disease, orthopedic surgery, burn care, toxicology, veterinary care, etc), any specialty service may be accessed through an emergency department at a tertiary care medical center. The ready-access services and the overall program are regularly reviewed and updated. Over its initial three years, the ADVISOR system participated in hundreds of training calls and 156 real-world calls,[3] saving millions of dollars in avoided evacuations and providing well-appreciated support, according to feedback.

Teleconsultation in the AOE is supported according to priority and time constraints (Table 9-1). Direct patient care appointments are managed predominantly on a regional basis. Units must coordinate with their chain of command and regional health command to support direct patient care. Routine consultations through the Global Teleconsultation Portal will be answered within 24 hours. Place urgent and emergent consultations through the ADVISOR system. Both of the following sites require Common Access Cards.

- Register for the Global Teleconsultation Portal. https://info.health.mil/army/VMC/Pages/VMC/GTP.aspx
- More information about ADVISOR System is available. https://info.health.mil/army/VMC/Pages/VMC/OperationalMedicineAdvisor.aspx

Limitations

The most significant limitation of telemedicine in general, and particularly during PC, is time. Telemedicine takes more time than physical medicine. Two main challenges place time pressure on the care team utilizing telemedicine:

1. REs cannot be present physically at the point of care. REs can only know the constraints or challenges of the physical environment in which PC occurs if the LC or a future technology solution informs them. Time limitations may cause REs to rush, make assumptions, or limit consultation based on priorities.
2. Telemedicine consults are directly affected by the LC's ability to effectively assess a casualty, provide correct data to a RE, and communicate information accurately and reliably.

Best Practices

Best practices for telemedicine use during PC are summarized in Exhibit 9-1. Concepts for PACE planning for telemedicine are summarized in Table 9-2.

Table 9-1. Operational Virtual Health Support.

The ADvanced VIrtual Support for OpeRational forces (ADVISOR) system provides synchronous and asynchronous teleconsultation support for deployed military caregivers. The type of support and interface platform depends on urgency of the consult. Direct patient care telemedicine is not yet incorporated into the ADVISOR system, but it is supported by other solutions in pilot projects.

ADVISOR			Other solutions
Synchronous phone through call coordinator; can be escalated to real-time video depending on local capabilities		**Global Teleconsultation Portal (GTP)**	**Varies by region**
Emergent virtual critical care	**Urgent specialty services**	**Routine**	**Direct care**
Consult within minutes	Consult within minutes	Response within *24 h*	It must always be planned ahead
Life-threatening or potentially life-threatening conditions like: • Shock • Respiratory failure • Renal failure • Liver failure • Complex wounds • Polytrauma (cont.)	Urgent consults are all other cases that do not fall under the routine or emergent categories Urgent consults usually require specialty medical advice (eg, general surgery, orthopedic surgery, infectious disease, [cont.]	*Normal* vital signs Not going to deteriorate in 24 h	Direct patient care is *not* teleconsultation DC uses VTC to evaluate and treat patients who are in a different location

(**Table 9-1** *Continues*)

Table 9-1 *Continued*

ADVISOR			Other solutions
Synchronous phone through call coordinator; can be escalated to real-time video depending on local capabilities		Global Teleconsultation Portal (GTP)	Varies by region
Emergent virtual critical care	**Urgent specialty services**	**Routine**	**Direct care**
column cont.	*column cont.*		
• Burns • Severe infection/sepsis • Crush injuries • Severe electrolyte abnormalities • Encephalopathy/severe TBI • Abnormal vital signs • Complex arrhythmias • Poisonings	toxicology, pediatrics, behavioral health, burn care) and would benefit for synchronous communication between the local caregiver and the remote consultant		

Abbreviations: DC, direct care; TBI, traumatic brain injury; VTC, video teleconference.
Reproduced with permission from Telemedical support in austere and operational environments. In: Pamplin JC, Borgman MA, eds. *Fundamental Critical Care Support: Resource Limited*. Society of Critical Care Medicine; 2020:363-374.

Exhibit 9-1. Best Practices for Telemedicine Support in the Austere and Operational Environment

Telemedicine skills must be practiced by local caregivers and remote experts for interactions to be effective and efficient. Ideally, this care team should train together using simulated patient care to optimize communication and ensure technology choices match clinical needs.

Before traveling to the AOE, care teams should develop a PACE plan for telemedical support that includes when and how (technology) to use telemedicine.

Local caregivers must recognize when to "make the call." Conceptually, the "sicker" a patient is, the earlier and more frequently the local caregiver should engage with the remote expert. If available, employ continuous monitoring for an extended consultation (ie, tele-critical care).

Effective and efficient teleconsultation takes practice, but it can be improved through the following four tasks:

1. Use a script familiar to the local caregiver and the remote consultant.
2. Send background information using asynchronous technology ahead of synchronous telemedicine encounters.
3. Use closed-loop communications that include intentional pauses in communication for read-back and clarification.
4. Have the remote expert document the telemedicine encounter and send that documentation with a summary of recommendations to the local caregiver.

Solve technical challenges using a well-developed and practiced PACE plan.

Abbreviations: AOE, austere and operational environment; PACE, primary, alternate, contingency, emergency.

Adapted with permission from the Society of Critical Care Medicine from Vasios 3rd WN, Pamplin JC, Powell D, et. al. Teleconsultation in Prolonged Field Care Position Paper. *J Spec Oper Med.* 2017;17:141-144.

Table 9-2. Example PACE Plan[a] for Telemedicine Support in the Austere and Operational Environment

	Patient care plan	Telemedicine technology
Primary	Use local assets; evacuate the patient; pre-position resources (eg, if you expect to need a surgeon, have an operating room and a surgeon locally available)	**Power**: electrical grid **Network**: fiber or cable internet **Equipment**: dedicated telemedicine equipment (eg, VTC exam station, room camera, augmented reality device, peripheral devices)
Alternate	Use established telemedicine relationship to support care in place or during evacuation	**Power**: solar cell battery **Network**: 4G/LTE cellular network **Equipment**: mobile phone/tablet +/- peripheral exam equipment
Contingency	Use ad hoc telemedicine relationships (ie, "phone-a-friend") to support care in place or during evacuation	**Power**: gasoline generator **Network**: satellite **Equipment**: laptop/desktop computer, digital camera, email
Emergency	Use un-approved, non-standard local solutions (eg, local economy, high-risk care by untrained individual) to achieve "best possible" outcome	**Power**: batteries **Network**: telephone, radio **Equipment**: phone, radio

Abbreviations: PACE, primary, alternate, contingency, emergency; VTC, video teleconference

[a] Examples show general AOE conceptual care plan and telemedical technology plan. The telemedicine technology PACE plan supports the alternate and contingency patient care plans. Consider the power, network, and equipment items below to be independent plans that could be mixed and matched according to need and functioning. Thus, the primary power plan could support the alternate network and contingency equipment. Generally, the technology plan should build from most reliable to least reliable.

Best practices for facilitating efficient telemedicine include the following:

- Practice telemedicine during training.
- Maintain an easily sharable document that describes the PACE plan, available supplies, and equipment. An example of this is in the Joint Trauma System (JTS) Clinical Practice Guideline for Telemedicine Guidance in the Deployed Setting, CPG ID: 94. https://jts.health.mil/assets/docs/cpgs/Telemedicine_Deployed_Setting_19_Sep_2023.pdf
- Provide this information to the RE before the consultation. Update this information as mission, personnel, and equipment status change.
- A script to convey information efficiently and comprehensively during a telemedicine encounter reduces telemedicine consultation time, increases information transfer, and reduces cognitive load and stress for inexperienced caregivers. See an example in Appendix B of the Telemedicine Guidance in the Deployed Setting Clinical Practice Guideline.

Summary

Telemedicine provides access to remote expertise not otherwise available during PC and may improve patient outcomes and caregiver mental health. Effective use of telemedicine during PC requires trust developed through training and a tested PACE plan. The use of telemedicine during PC is a skill that improves with practice.

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Chapter 10

NURSING FOR THE PROLONGED CARE ENVIRONMENT

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Introduction

Rapid casualty evacuation from the point of injury to damage control surgical capabilities marked recent combat engagements in Afghanistan and Iraq. US military medical planners operationalized historical doctrine to orchestrate patient movement on the battlefield from the point of injury to appropriate injury-specific medical care within 1 to 4 hours. However, future military operational constraints combined with evacuation capability limitations may require periods of prolonged care (PC) at or near the point of injury. These limitations emerged due to air superiority challenges with near-peer adversaries and the tyranny of distance associated with ground combat medical evacuation. Military medical personnel should be prepared to provide advanced diagnostic, surgical, and prolonged nursing care in remote, austere casualty care environments.

Key Principles

- Unlike traditional hospitalized care, the primary objective of PC is to maintain stability and optimize the physiologic status of casualties while mitigating pain as they await evacuation and definitive care.
- Nursing includes continuous cycles of assessment, problem identification, goal setting, intervention, and evaluation of the effectiveness of the intervention.
- Nursing care is resource-intensive (supplies, equipment, people, and time).

- Effective caregivers prioritize care efforts within the context of the individual patient, all other patients, and resource availability.
- Hands-on experience (real world or simulation) is the best way to prepare for nursing care demands; cross-training is essential.
- Elements of care are provided at different times and in other ways, depending on the resources available and the caregiver's skill level.
- Patient care documentation on PC flowsheets facilitates subsequent casualty care and enables performance improvement tracking and research efforts.
- The unique challenges and conditions of out-of-hospital care may require reconsidering traditional nursing roles and adding flexibility to modify or otherwise rethink conventional scopes of practice and procedures.

General Considerations

At its core, nursing care aims to restore patient health and prevent further harm (eg, deep vein thrombosis, pneumonia, pressure injury, wound infection, or urinary tract infection). To achieve this, nurses continually monitor patients through cyclic iterations of assessment, problem identification, goal setting, intervention, and evaluation of intervention efficacy. Concurrently, when multiple threats exist, nurses must consider the importance of the threats and triage their efforts to achieve the greatest good for the patient. In a more robust setting such as a hospital, these processes require significant logistical support (eg, equipment and supplies) to provide a clean, safe environment for patient care.

Nurses routinely use technology to enhance their capabilities to monitor and intervene. Some technologies facilitate close monitoring of critically ill patients, while others simultaneously facilitate the general monitoring of several patients. Austere clinical settings requiring PC have several resource, technology, and logistical support challenges. Nurses must adapt to these resource constraints while facing unpredictable casualty care volumes. Thus, threat and intervention triage must occur within the context of the individual patient, all other patients, and resource availability.

Providing lifesaving nursing care is resource-intensive in any environment. The resources required include supplies, equipment, people, and time. The need for supplies and equipment is self-evident. However, the demand for people and time may need to be more apparent. Patient monitoring requires at least one person to be attentive to the patient's needs for the time necessary to complete a targeted assessment. If the care provider identifies a need to intervene during the assessment phase, the team must allocate additional time to intervene, reassess, and complete the initial assessment. Depending on the patient's needs, the intervention may require an extra person (or more). These individuals will be temporarily unavailable for other mission-related activities. An increase in injury severity or the number of patients requiring care increases the demand signal for personnel and time dedicated to monitoring and caring for patients.

Providing nursing care in PC settings requires team members with the following knowledge, skills, and training:

- Military medical personnel of all skill levels must understand normal pre-injury physiology and post-injury pathophysiology.
- Foundational nursing skills are required for refining care and advancing to increased care complexities with resource limitations in austere settings (eg, limited water and electricity).
- Hands-on experience and exposure are the best preparation for operating within a resource-limited environment.
    - Real-life nursing care experience. Shadow or intern-like programs increase experience levels in new care providers.
    - Simulation. Simulation does not require expensive mannequins or technology. It is more important that the simulation nearly represent the intended real-life scenario. Simulations are effective and low-cost training strategies.
- Cross-training among nonmedical personnel to assist with basic nursing care is essential because nursing care for more than one patient may require help from multiple individuals.

The remainder of this chapter covers specific elements of nursing care relevant to a PC environment. Many of these elements of nursing care are also basic soldiering skills that do not need

specialized training. The described elements are not inclusive of all nursing care and are not duplicative of other care elements described elsewhere in this text. Since these elements of care apply across nearly any condition, injury, or illness, they are not presented according to the MARCHPAWS (massive hemorrhage, airway, respirations, circulation/crisis standard of care/communication, hypothermia/hyperthermia/head injury, pain control, antibiotics, wounds, and splints) mnemonic commonly used in tactical combat casualty care or prolonged care discussions. Additionally, the ***minimum-better-best*** paradigm clarifies how to address the elements of care with increasing resource availability.

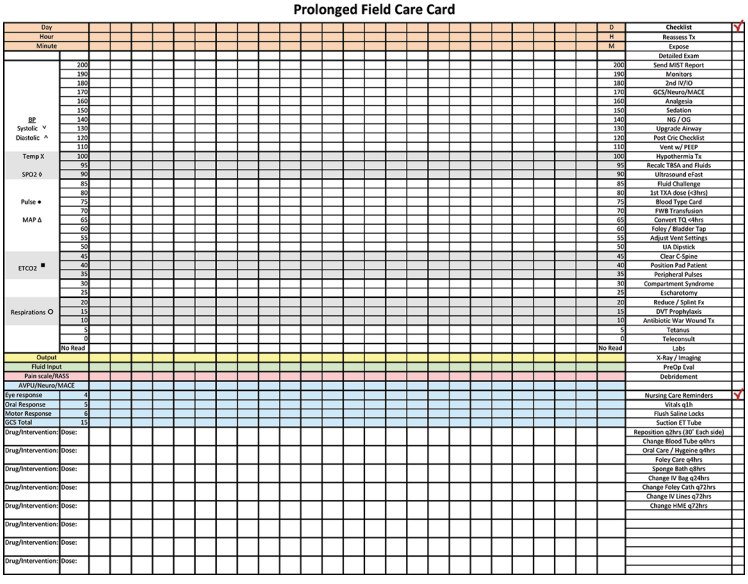

Figure 10-1. Joint Trauma System prolonged field care flowsheet, page 1. Reproduced from Ostberg D, Loos P, Mann-Salinas E, et al. Joint trauma system clinical practice guideline: nursing intervention in prolonged field care (CPG ID: 70), appendix A. Joint Trauma System website. Published July 26, 2022. Accessed July 28, 2023. https://prolongedfieldcare.org/wp-content/uploads/2023/04/PFC-Flowsheet-v24.1-26JUL2022.pdf

Elements of Care

Elements of care apply at varying times and in different ways, depending on the patient's condition, the context of the care environment, the resources available, and the skill level of the care providers. Use all these factors to determine the best methods for caring for the casualty to prevent harm and support healing. Document all care provided, ideally on the prolonged field care flowsheet (Figures 10-1 and 10-2). Documentation of care provides the medical teams at higher levels of care with information that informs patient care decisions. In addition, prehospital documentation provides mechanisms to conduct trauma-system performance improvement to increase survivability.

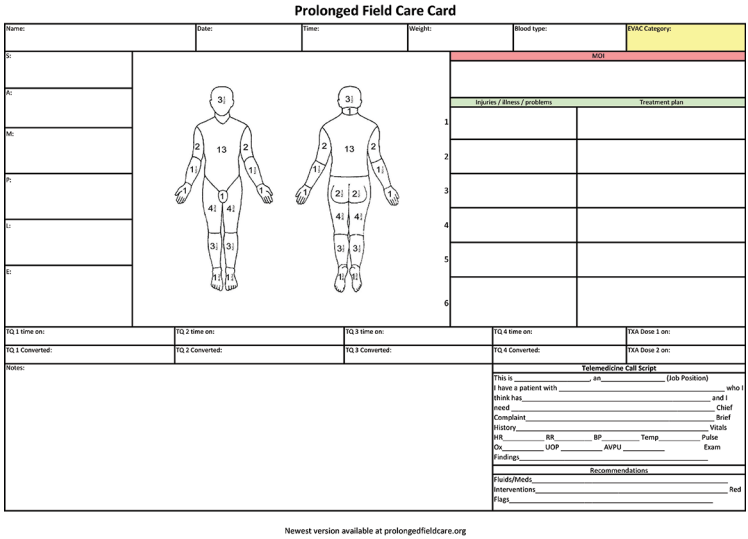

Figure 10-2. Joint Trauma System prolonged field care flowsheet, page 2. Reproduced from Ostberg D, Loos P, Mann-Salinas E, et al. Joint trauma system clinical practice guideline: nursing intervention in prolonged field care (CPG ID: 70), appendix A. Joint Trauma System website. Published July 26, 2022. Accessed July 28, 2023. https://prolongedfieldcare.org/wp-content/uploads/2023/04/PFC-Flowsheet-v24.1-26JUL2022.pdf

Continuous Needs

Psychosocial. After an injury, casualties often experience fear and anxiety. Sometimes casualties may become incoherent or lose consciousness. Regardless of their condition, address these individuals respectfully and in a manner that maintains their dignity.

- At a ***minimum***, speak calmly and address any of the casualty's concerns.
- A ***better*** option is to support the casualty using a caring touch and active listening to ensure they understand all procedures performed on or for them.
- The ***best*** option is also to help the casualty rest and sleep, which will help minimize some neurologic symptoms, such as delirium.

Body Temperature. Abnormal body temperature can be detrimental to operational readiness. Options to monitor body temperature include the following:

- At a ***minimum***, assess the casualty hourly by placing the back of your hand on their face or chest.
- A ***better*** option is to insert an oral thermometer into the casualty's mouth, axilla, or groin. Alternatively, use a digital forehead or ear thermometer.
- The ***best*** option is to monitor the casualty's core body temperature with a rectal probe or via a central venous catheter.

At the extreme, a casualty who is too hot (**hyperthermia**) may suffer from neurologic symptoms (eg, dizziness, nausea, confusion, agitation), redness of the cheeks and forehead, and an inability to sweat. Treatment options for hyperthermia include the following:

- At a ***minimum***, ensure the casualty rests out of the sun with their skin exposed to air and provide water for hydration.
- A ***better*** option is to apply cold, wet compresses to the axilla, groin, and neck. Do not use ice, as this may cause the casualty to cool too quickly and may damage the skin if left in place too long. These casualties should hydrate with water containing

electrolytes (eg, sodium and potassium) and small amounts of sugar. Alternatively, assist the casualty in eating foods (as tolerated) that contain electrolytes, such as soups, processed meats, chips, or pretzels.
- The ***best*** option is to cool the casualty using cooled, forced air and infusions of cooled electrolyte-containing sterile fluids.

A casualty who is too cold (**hypothermia**) may become lethargic and slow to respond to stimuli. After the injury, a hypothermic casualty may become more acidotic, negatively affecting their ability to clot and stop bleeding. Treatment options for hypothermia include the following:

- At a ***minimum***, wrap the casualty in dry clothes or blankets.
- A ***better*** option is to wrap the casualty in a commercially available hypothermia prevention kit containing an air-activated heating element.
- The ***best*** option is to add warmed, forced air and infusions of warmed sterile fluids.

Regardless of the condition and the methods used to support the casualty, **be careful not to change the body temperature too quickly**. Recheck the temperature every 15 minutes after beginning the treatment to achieve a change rate of no more than 2.5 °F per hour.

Head Injury. A casualty with a head injury may suffer from brain swelling. One method to lessen the effects of brain swelling is to provide a path for cerebral fluids to exit the cranium. Elevate the casualty's head to a 30° angle from the surface on which they are lying. Options to elevate the casualty's head include the following:

- At a ***minimum***, lay the casualty against a rucksack or backpack.
- A ***better*** option is to use pillows or blankets to support the casualty's head.
- The ***best*** option is to use a NATO litter backrest.

It is also vital to place the casualty's head in a neutral position, facing forward, to prevent manual obstruction of blood and lymph vessels on either side of the neck.

Assisted Ventilation. An airway adjunct and ventilator support may be required if the casualty cannot breathe independently. Assisted ventilation options follow:

- To provide the ***minimum*** level of ventilator support, ventilate the casualty using a bag-valve-mask (BVM) device (with or without supplemental oxygen). You must remain at the casualty's side for BVM ventilation. When using the BVM, pay attention to obtaining and maintaining an appropriate seal. If an airway adjunct connects directly to the BVM, secure it to ensure the adjunct does not migrate out of the oropharynx and trachea.

Note: In situations with more than one casualty requiring BVM support, one person can temporarily support two casualties by alternating between them after two or three BVM breaths.

- A ***better*** option is to deliver ventilator support through a commercially available mechanical ventilator without integrated supplemental oxygen. This type of ventilator allows the caregiver to attend temporarily to other casualty needs, other casualties, or other mission requirements. However, monitor mechanical ventilators at least every 15 minutes to ensure proper function and support to the casualty.
- A commercially available mechanical ventilator with integrated supplemental oxygen is the best option to support a casualty.

Assisted ventilation can be **titrated** to patient demand by maintaining greater than 90% oxygen saturation via pulse oximetry. When providing ventilator support via BVM, increase or decrease the BVM rate or the volume of air instilled to maintain oxygen saturation (by compressing more of the BVM or using a larger bag). When using mechanical ventilation, titrate by adjusting the following ventilator parameters (one at a time, waiting 5-10 min between adjustments):

- Tidal volume (the amount of air forced into the lungs).
  - Generally, set the tidal volume at approximately 6-8 mL of air per 1 kg of body weight.
  - Tidal volume should not exceed 8 mL of air per 1 kg of body weight (consult a physician) to prevent lung damage.

- Respiratory rate. Increased respiratory rate should result in increased oxygen saturation.
  - Generally, set the respiratory rate at 12-16 breaths per minute.
  - Generally, do not exceed 20 breaths per minute (consult a physician) to prevent respiratory alkalosis.
- Positive end-expiratory pressure (PEEP). Increased PEEP should result in increased oxygen saturation.
  - Generally, set at 5 cm of water (cm H_2O).
  - Generally, do not exceed 10 cm H_2O (consult a physician) to prevent the ventilator plateau pressures from exceeding 30 cm H_2O, which could result in lung injury.
  - Higher levels of PEEP could result in lower cardiac output; monitor heart rate and blood pressure frequently and adjust PEEP downward if there is a significant change.

Whether using the BVM or mechanical ventilation, adjust the oxygen concentration or flow rate if supplemental oxygen is available. Higher concentrations or flow rates should result in higher oxygen saturation.

Intravenous or Intraosseous Fluids. An essential aspect of caring for a traumatically injured casualty is an intravenous or intraosseous infusion of fluids. Once initiated, these fluids often run continuously to support hydration and replenish intravascular volume. However, to prevent fluid volume overload, calculate the infusion rate correctly and monitor it frequently (hourly, at a minimum). Standards to monitor and adjust the fluid infusion rates follow:

- The ***minimum*** standard is to calculate the rate based on the number of drops seen per minute in the chamber of the infusion set. Military infusion sets are usually 10- or 15-drop sets. In a 10-drop set, 10 drops equal 1 mL of fluid. In a 15-drop set, 15 drops equal 1 mL of fluid. Count the number of drops seen in the chamber over 60 seconds to calculate the infusion rate. Alternatively, count the drops for a shorter time and multiply them to achieve a drops-per-minute rate. For example, if counting drops for 15 seconds, multiply that number by 4 to calculate the number of drops seen in 1 minute (60 seconds).

Table 10-1. Intravenous Tubing Drop Rate

Flow rate (mL/h)	10 drops = 1 mL (drops per min)	15 drops = 1 mL (drops per min)
10	2	2
25	4	6
50	8	12
75	12	19
100	17	25
125	21	31
150	25	37
200	33	50
250	42	62
500	83	125
1000	167	250

Refer to Table 10-1 to identify the infusion rate based on the number of drops per minute. After determining the infusion rate, adjust the rate up or down by moving the roller clamp on the infusion tubing.

Note: If the infusion set chamber is too full to see the drops, invert the chamber so that the fluid bag is below the chamber, and squeeze the chamber to expel some of the fluid into the bag.

- A ***better*** option for controlling the infusion rate is to place a "dial-a-flow" device between the casualty and the infusion set. This device allows gravity to pull fluid through it at a specified rate (identified by numbers on the device).
- The ***best*** option for controlling the infusion rate is to use a commercially available mechanical infusion pump to infuse fluids at specific rates.

Pressure Injury Prevention. Immobile casualties may develop soft tissue injuries to the skin where bony portions of their body support some or all of their body weight. These injuries result from decreased blood flow to these tissues and develop

after prolonged periods (more than 2 h) without relief from the body weight pressure. If the casualty is supine, these injuries commonly develop at the back of the head (occiput), tailbone (sacrum and coccyx), elbows, and heels. Pressure injuries also can develop in other areas, depending on the casualty's position. For example, if the casualty lies on their side, injuries could develop on the lateral portions of the ankle and foot, as well as the hip and pelvis. Options to prevent pressure injuries include the following:

- At a ***minimum***, turn the supine casualty from side to side every 2 hours. Do this regardless of the casualty's neurologic or respiratory status. However, be careful to prevent dislodging artificial airways, chest drainage devices, or other equipment. To perform the turn, rotate the casualty onto their side, and place rolled blankets or clothes behind their head and back. If there is concern over a head or neck injury, place the blankets or clothes in a position that maintains cervical neutrality. Then, lay the casualty back onto the blankets or clothes so that most of their weight is supported by the latissimus and gluteal muscles, as well as the muscular portions of the thigh and calf. Additionally, place blankets or clothing under the casualty's ankle and between their legs so that the bony portions of the knees and ankles do not touch. Finally, pull slightly forward the arm on which the casualty is lying to prevent pressure injury development on that elbow.
- A ***better*** option is to place the supine casualty on a commercially available air or foam pad or mattress (up to 1 in. thick) and continue to turn the casualty side to side as described earlier.
- The ***best*** option is to place the supine casualty on a commercially available air or foam pad or mattress greater than 1 inch thick and continue to turn the patient side to side as described earlier. A thicker pad or mattress is better because the casualty's body weight compresses it less.

Regardless of the option, **check under the casualty** to ensure that objects, such as rocks or treatment devices, are not present. An object under the casualty places similar amounts of pressure on the skin as bone, compressing the skin, preventing blood flow, and causing pressure injuries.

Moisture also increases the risk of developing pressure injuries. Moist skin becomes macerated, which causes the bonds between the skin layers to loosen, making the skin more prone to damage. Therefore, **keep the casualty's skin dry**, particularly in bony areas prone to pressure injury. Moisture may result from sweat, blood, feces, or other body fluids. Also, increased moisture may occur after care providers rinse wounds or bathe the casualty. Options to keep the casualty dry include the following:

- At a ***minimum***, remove all wet clothing and replace soaked bandages.
- A ***better*** option is to towel dry all portions of the casualty's body that will touch the ground or lying surface.
- The ***best*** option is to remove wet clothing, towel dry the casualty, and place them on a surface that allows fluids to move away from their skin.

Hourly Needs

Nonmedical Interventions. Part of helping the casualty is attending to their comfort needs. Nonmedical options include the following:

- At a ***minimum***, caregivers may work to distract the casualty or perform guided imagery (a visualization practice).
- A ***better*** option is to add splints to injured limbs and joints, pad bony prominences, and provide ice (or warm) packs to injured or swollen areas.
- The ***best*** option is to combine these elements of care.

Lip care. Because the lips are needed to eat and drink—essential to hydration and healing—it is vital to prevent them from becoming painful, dry, and cracked. Failure to do so may limit oral intake, resulting in dehydration and impaired healing. Lip care options include the following:

- At a ***minimum***, apply a commercial lip balm to the casualty's lips.
- A ***better*** option is to use a moisturizing lotion on the lips.
- The ***best*** option is to apply petroleum jelly to the lips.

Cough and Deep Breathing Exercises. Cough and deep breathing exercises are essential to prevent pneumonia because they expand the lungs and open the alveoli to mobilize secretions that might collect and harbor bacteria. Cough and deep breathing options include the following:

- At a ***minimum***, encourage the casualty to take 10 deep breaths per hour and actively cough after each one.
- A ***better*** option is for the casualty to do this while sitting upright.
- The ***best*** option is for the casualty to breathe deeply using an incentive spirometer and then actively cough after each breath while sitting upright or turning to one side.

Airway Management. Airway maintenance requires consistent, frequent attendance to ensure the patient moves air in and out of the lungs well enough to support physiological needs. The more advanced the airway, the more attention and skill are required. One of the basic requirements for airway management is **suctioning the mouth or airway** (if an airway adjunct is in place), as follows:

- At a ***minimum***, for suction, use a Toomey or a 60-mL syringe attached to a 25-cm long portion of plastic intravenous tubing that is narrower than the airway.
- A ***better*** option is to suction the airway using a commercial, manual suction device.
- The ***best*** option is to suction the airway using a commercial, powered suction device and a suction catheter integrated into the airway circuit.

Consider suctioning the airway hourly. More frequent suctioning depends on the casualty's need. Be careful not to damage the oropharynx and trachea during suctioning by roughly forcing the suction tubing beyond the end of the airway adjunct.

Needs Every 2 Hours

Repositioning and Padding. Reposition the casualty every 2 hours to prevent pressure-related injuries to the back, buttocks, and bony prominences. Repositioning options include the following:

- At a ***minimum***, turn a supine casualty from one side to the opposite side, positioning them so that their weight rests on muscular (rather than bony) portions of the body, such as the latissimus and gluteal muscles. If you cannot avoid bony prominences, pad them with clothing or textiles.
- A ***better*** option is to pad the bony prominences with pillows or blankets.
- The ***best*** option is to put pillows along the length of the casualty's body (while turned) and between their legs.

Splinting. Injuries to bones and joints require splinting to immobilize the area, which may improve pain and prevent further injury. Splinting options include the following:

- At a ***minimum***, improvise splints using spare wood, branches, or other rigid material.
- A commercial splinting device, such as a SAM splint (SAM Medical Products), is a ***better*** option.
- The ***best*** option is to use a fiberglass splint lined with padding and held in place with elastic wraps or bandages.

Regardless of the splinting method, the objective is to splint the span of the injury and limit movement above and below the site. Once the splint is applied, assess at least every 2 hours for pulses distal to the injury. If palpating pulses is difficult, elevate the extremity to reduce swelling. A fasciotomy may be necessary if the pulses remain difficult to palpate and the pain becomes unmanageable.

Deep Vein Thrombosis Prevention. After a traumatic injury, the body is more prone to clotting, which is dangerous because the clots might dislodge from the original location and move through the body to the heart, lungs, or brain, causing a dangerous loss of blood circulation in that region. Immobility associated with injury compounds this because clots form more

readily when blood pools in the veins for too long. Clots can develop in any vein but are most problematic when they form in the larger vessels of the legs. The following options prevent blood from pooling:

- At a ***minimum***, massage or move the muscles of the lower extremities.
- A ***better*** option is to continue the massage and movement while applying compression stockings or moderately wrapped elastic bandage wraps to improve venous return.
- The ***best*** option is to supplement the previous options with commercially available pneumatic compression garments that intermittently inflate.

Regardless of the method used, take care around wounds to the lower extremities.

Needs Every 12 Hours

Oral Care. Oral care is essential to prevent further injury or infection, particularly for patients who cannot maintain their airways. If the patient cannot maintain an airway, they likely cannot swallow, causing saliva and other fluids to collect in the mouth and oropharynx. The teeth can harbor bacteria that proliferate in the pool of fluid. This liquid may seep past the epiglottis and into the lungs, where pneumonia develops, and may progress to acute respiratory distress syndrome (ARDS). The following options help prevent pneumonia and ARDS that may result in patients who cannot maintain an airway:

- At a ***minimum***, conduct oral care for the patient using gauze, water, and a gloved finger. Soak the gauze in water and use the gloved finger to brush the inner and outer aspects of the teeth.
- A ***better*** option is to use a toothbrush and commercial toothpaste.
- The ***best*** option is to brush the teeth and gums with chlorhexidine rinse to reduce the number of bacteria in the mouth. When complete, suction the mouth and oropharynx out using a manual or commercially available product, as described earlier in the airway section of this chapter.

Needs Every 24 Hours

Wound Care. Irrigating the wounds every 24 hours is vital to prevent bacteria from colonizing and proliferating in wounds. Irrigation is the primary means of wound debridement until the patient arrives at a facility with surgical capability. Wound care options include the following:

- At a ***minimum***, expose the wound and pour potable water across the wound. If the water was boiled to make it potable, let it cool to room temperature before using it on the wound.
- A ***better*** option is to cleanse the wound by squirting the potable water through an 18-gauge angiocatheter attached to a 10-mL syringe.
- The ***best*** option is to squirt sterile saline, sterile water, or an antimicrobial solution (eg, Dakin solution) through the catheter and syringe combination.

Additionally, consider replacing the wound dressing as part of the irrigation process. Replacing the dressing also prevents the colonization of bacteria in the wound. Wound dressing options include the following:

- At a ***minimum***, reinforce the dressings if supplies are limited and no clean dressings are available (particularly if the wound is still bleeding).
- A ***better*** option is changing the dressings when soiled to allow for continued use of dressings on wounds that are not actively bleeding.
- The ***best*** option is to change the dressing every time the wound is irrigated.

Personal Hygiene. In addition to simply making a person feel better, personal hygiene is integral to infection prevention. As such, perform personal hygiene for the patient regularly, as follows:

- At a ***minimum***, cleanse an injured person (face, armpits, and groin) at least daily using soap, water, and a gauze roll.
- A ***better*** option is to clean as above using a washcloth or commercially available baby wipes.
- The ***best*** option is to cleanse the casualty using chlorhexidine-impregnated cleansing wipes. If the casualty has a Foley

catheter, cleanse the area around the catheter insertion site every 12 hours, as described above.

Needs at Varying Times

Oral or Nasal Tube Management. The soft tissues of the mouth and nose are prone to developing device-related pressure injuries. A device inserted into one of these openings (eg, endotracheal tube or nasogastric tube) is pressed against the tissue to prevent the device from inadvertently moving in or out of the body. To prevent device-related pressure injuries, cleanse the skin and rotate the device around the mouth or nares once every 12 hours. Once the device is rotated to a new position in the mouth or nose, secure it as follows:

- At a ***minimum,*** use string or umbilical tape.
- A ***better*** option is to attach medical tape to the tube and then to the casualty's nose or the upper lip below the nose.
- The ***best*** option is a commercially available airway-securing device. Sometimes, the ***best*** option might be to secure the airway or feeding tube by wiring the tube to the casualty's teeth. Additionally, string or umbilical tape may be the ***best*** option for casualties with burns to their face because tape and commercial holders may slip due to exudate developing on the face.

If the casualty has an orogastric or nasogastric tube, it is crucial to assess the tube for patency because the feedings and body fluids could cause the tube to become blocked. If feeding the patient through the tube, assess the stomach for proper emptying so it does not become overfull. If the stomach overfills, the patient will vomit, introducing a risk for aspiration and pneumonia. Options to assess stomach contents follow:

- At a ***minimum***, check for residual stomach contents every 12 hours using a Toomey syringe, and then flush with water (1-2 oz).
- A ***better*** option is to check for residual contents and flush every 8 hours.
- The ***best*** option is to check for residual contents and flush every 4 hours.

Bowel Management. Care for casualties after bowel movements must happen at the time they occur. Options for bowel management follow:

- At a ***minimum***, cleanse the perineum as described for personal hygiene. If dressings or hypothermia prevention kits become soiled, replace them with clean ones.
- A ***better*** option is to prevent the dressings or hypothermia management kits from becoming soiled by placing a cloth, linen, or plastic barrier between the anus and the dressing or kit.
- The ***best*** option is to clean and prevent soiling while adding a barrier cream to the buttocks, sacrum, and perineum to prevent skin breakdown.

Intravenous or Intraosseous Site Care. Sites of line insertion are a potential source of infection. It is crucial to assess and cleanse these sites regularly to reduce the risk of infection, as follows:

- At a ***minimum***, flush the line with sterile saline to maintain patency, assess the site for signs of infection every 12 hours, and change the infusion tubing every 96 hours.
- A ***better*** option is to flush the line, assess for signs of infection every 8 hours, and change the infusion tubing every 74 hours.
- The ***best*** option is to flush the line, assess for signs of infection every 4 hours, and change the infusion tubing every 48 hours.

Convert the intraosseous site to an intravascular site within 24 hours.

Note: Intraosseous sites are prone to skin breakdown due to the device's pressure placed on the skin.

Summary

For additional Prolonged Care guidelines, go to the Joint Trauma website. https://jts.health.mil/index.cfm/PI_CPGs/cpgs

Chapter 11

PRACTICAL PROLONGED CARE MANAGEMENT OF CHILDREN

Andrew W. Moulton, MD, and Matthew A. Borgman, MD

Introduction

Modern combat and humanitarian operations must anticipate and plan for children's medical care. Children accounted for up to 11% of all bed days at Role 3 medical facilities during operations in Iraq and Afghanistan. Medical providers should prepare for the common procedures and conditions involving children in these austere settings. Most adult guidelines are applicable for older children around puberty or 40 kg.

Key Principles

- Plan for the care of children before operations in terms of training, equipment, and resources.
- Identify key similarities between adults and children.
- Note the resources required for prolonged care of children.
- Have available references for pediatric equipment sizing and medication dosing.

Airway

The tongue is often a cause of airway obstruction in young children. Adjust the child's head position. If necessary, place airway adjuncts (nasopharyngeal or oropharyngeal) to open the airway; however, size them appropriately. Consider the following when managing airway obstruction in children:

- Only intubate if you have sufficient resources and experience. Intubating will tie up personnel and exhaust medical resources.
- Cricothyrotomy and tracheostomy are very difficult, technical procedures in children under 10.
- Treat upper airway obstruction due to croup or post-extubation stridor with intravenous (IV) steroids (dexamethasone 0.6 mg/kg) and racemic epinephrine 2.25% (0.5 mL in 2.5 mL saline).

- If intubation is necessary, use the endotracheal tube (ETT) formulas below:
  - Uncuffed ETT size = (age in years ÷ 4) + 4;
    cuffed ETT size = (age in years ÷ 4) + 3.
  - ETT depth (cm) from lip to mid trachea = ETT size × 3.

Breathing

Respiratory infections are one of the top causes of morbidity and mortality in austere settings. Use of noninvasive support, if available (eg, nasal cannula, high flow nasal cannula, bubble continuous positive airway pressure [CPAP]), is much preferred over invasive ventilation given both the resource requirements and the added complexity an intubated patient confers.

- If available and indicated, dose high flow nasal cannula starting at 1 to 2 L/kg/min for respiratory insufficiency (typically due to bronchiolitis or pneumonia). Adjust flow based on the work of breathing.

Table 11-1. Normal Vital Signs by Age

Age	Weight (kg)[a]	Respiratory rate (breaths/min)	Heart rate (beats/min)	Systolic blood pressure (mm Hg)[b]
Premature infant	<3	40-60	130-170	45-60
Term newborn (<28 d)	3	35-60	120-160	60-70
Infant (1 mo-1 y)	4-10	25-50	110-150	70-100
Toddler (1-2 y)	10-13	20-30	90-130	75-110
Young child (3-5 y)	13-18	20-30	80-120	80-110
Older child (6-12 y)	18-40	15-25	70-110	90-120
Adolescent (13-18 y)	>40	12-20	55-100	100-120

[a] Weight norms based on US children. Expect lower weights in countries where malnutrition is more prevalent.
[b] For children 1 to 10 years old, use the following equation: 70 + 2 (age) = lowest acceptable systolic pressure for age.
Reproduced from: Creamer KM, Fuenfer MM. *Pediatric Surgery and Medicine for Hostile Environments.* 2nd ed. Borden Institute; 2016:4.

- Configure the bubble CPAP using a nasal cannula. Attach the inspiratory limb to a 5 to 10 L/min O_2 source and insert the expiratory limb of the cannula (can cut a standard nasal cannula) into a canister of water, the depth roughly correlating to pressure (eg, 5 cm H_2O).
- If the patient requires ventilatory support and resources are available, set the pediatric ventilator (initial) as follows:
  - Tidal volume 6 to 8 mL/kg.
  - Rate between 12 (adolescents) and 24 (infants).
  - Positive end-expiratory pressure like adults.
  - Inspiratory time (I-time) between 0.5 s (infants) and 1.0 s (adolescents).

Indications for chest tubes are the same for children and adults. If pediatric sizes are unavailable, consider improvising using adult-size ETTs with a valve device or glove.

Circulation

At a minimum, monitor blood pressure and heart rate (Table 11-1).

Note: Cardiac output primarily depends on heart rate for infants as they cannot increase stroke volume when in progressive shock.

- Use continuous pulse oximetry with direct line-of-sight observation for more effective monitoring.
- Urine output (UOP) is a good surrogate for end-organ perfusion. Normal UOP is around 1 mL/kg/h in children.
- Children compensate for all forms of shock by releasing endogenous catecholamines to cause peripheral vasoconstriction. For this reason, they maintain blood pressure until shock is very severe, at which point it can drop precipitously if shock continues untreated.
- Steroids have similar indications as in adults and are generally administered if hypotension persists despite treatment with a vasopressor.
- If there is any concern for adrenal insufficiency (eg, recent or chronic use of steroids, virilized genitalia in infants, hyponatremia, and hyperkalemia), give steroids as soon as possible.

Neurologic

Seizure

Early treatment and identifying reversible causes are the key elements to treating seizures.

> **Note:** Children may present secondary to febrile seizures or infectious causes.

Metabolic abnormalities, including hypoglycemia and hyponatremia, are common and, when recognized, are quickly reversible. In austere environments without point-of-care testing, consider empiric treatment of hypoglycemia or hyponatremia if there is a clinical suspicion.

- Stabilize the patient by clearing airway secretions and providing oxygen by mask or nasal cannula.
- Benzodiazepines are the first-line treatment to abort an ongoing seizure (Table 11-2). IV/IO access is important in these settings; however, if this is not possible, administer diazepam rectally.
- Additionally, midazolam can be given via IV, IM, IO, intranasal, or buccal.
- If convulsions do not respond within 5 minutes after the first dose of benzodiazepines, a second dose may be given.
- Consider respiratory status and definitive airway management if more than two doses are required.
- After two doses of initial benzodiazepines, use long-acting anti-epileptics (Table 11-3).

Trauma

Head trauma is common in operational environments. Evaluating mental status and familiarity with the pediatric Glasgow Coma Scale will guide further management.

- As in adults, focus treatment on hypotension and hypoxia to improve outcomes.
- Assess for impending herniation, which may be indicated by:
  - Bradycardia.
  - Hypertension.

  - Abnormal respirations.
  - Asymmetric pupils.
- Give 5 to 10 mL/kg of hypertonic saline (3%) and consider an IV drip at 1 to 2 mL/kg/h if immediate transfer is impossible.

Sedation

Pediatric sedation is like adult sedation. For procedural sedation, the same medications dosed appropriately can be used (Table 11-4). A key difference in children is that the tongue is a frequent cause of obstruction, so having appropriate airway adjuncts (eg, oropharyngeal, nasopharyngeal, or laryngeal mask airways) and monitoring equipment (end-tidal CO_2) is essential.

Similar medications can be used for long-term sedation of ventilated children but with one exception. Propofol infusions can cause fatal metabolic acidosis in small children if used for longer than 24 to 48 hours.

Pain Management

Select pediatric pain medications using a tiered approach (Table 11-5). Give oral, non-opioid medications before using IV medications. When using high-potency opioids, closely monitor for respiratory and cardiovascular depression. Appropriate reversal agents should be available. See Chapter 8, Analgesia, for more information.

Environmental and Temperature Management

In the austere environment, exposure to the elements is likely, and both hypothermia and hyperthermia are significant threats to patients. Children are especially susceptible to hypothermia due to increased body surface area-to-mass ratios and lower subcutaneous fat content. Infants also cannot shiver and have immature thermoregulation. In contrast, exertional heat injury is more common in adolescents, while non-exertional heat injury occurs more frequently in infants, toddlers, and disabled children, primarily because they cannot leave their immediate surroundings. Infants with excessive blankets and bedding are at risk in warm environments.

Table 11-2. Benzodiazepines for Seizure Treatment

Medication	Dose	Maximum dose
Midazolam	0.2 mg/kg/dose buccal/IM/IN/IO/IV Continuous infusion for refractory status epilepticus at 0.05-2 mg/kg/h	10 mg/dose
Lorazepam	0.1 mg/kg IV	4 mg/dose
Diazepam	0.2 mg/kg IV 0.5 mg/kg rectal	10 mg IV 20 mg rectal

Abbreviations: IM, intramuscular; IN, intranasal; IO, intraosseous; IV, intravenous.
Data sources: Glauser T, Shinnar S, Gloss D, et al. Evidence-based guideline: treatment of convulsive status epilepticus in children and adults: report of the Guideline Committee of the American Epilepsy Society. *Epilepsy Curr*. 2016;16(1):48-61.
McIntyre J, Robertson S, Norris E, et al. Safety and efficacy of buccal midazolam versus rectal diazepam for emergency treatment of seizures in children: a randomised controlled trial. *Lancet*. 2005;366(9481):205-210.
Brophy GM, Bell R, Claassen J, et al; Neurocritical Care Society Status Epilepticus Guideline Writing Committee. Guidelines for the evaluation and management of status epilepticus. *Neurocrit Care*. 2012;17(1):3-23.

Table 11-3. Long-Acting Anti-Epileptic Medications

Medication	Dose
Phenobarbital	20 mg/kg IV (preferred under 6 months)[a]
Levetiracetam	20-60 mg/kg IV[b]
Fosphenytoin	20 mg PE/kg IV

Abbreviations: IM, intramuscular; IV, intravenous; NT, nasogastric; PE, phenytoin sodium equivalents.
[a] Can give IM—divide into two injections, diluted with equal parts normal saline.
[b] Give oral formulations via NG tube if no IV access.
Data sources: Brophy GM, Bell R, Claassen J, et al; Neurocritical Care Society Status Epilepticus Guideline Writing Committee. Guidelines for the evaluation and management of status epilepticus. *Neurocrit Care*. 2012;17(1):3-23.
Shenoi RP, Timm N, Committee on Drugs, Committee on Pediatric Emergency Medicine. Drugs used to treat pediatric emergencies. *Pediatrics*. 2020;145(1):e20193450.

Table 11-4. Common Sedation Medications for Pediatric Patients

	Medication	Dose	Onset	Duration
Nonpainful procedures	Midazolam	PO: 0.5 mg/kg (max 20 mg) IV: 0.1 mg/kg (max 6 mg) IN: 0.3-0.5 mg/kg (max 10 mg)	PO: 20-30 min IV: 3-5 min IN 5-10 min	0.5-2 h
Minor painful procedures	Fentanyl (+ Midazolam) Dexmedetomidine	IV: 0.5-0.1 mcg/kg IN: 1.5 mcg/kg IN: 0.5-2 mcg/kg	IV: immediate IN: 10 min 25 min	IV: 0.5-1 h IN: 20 min 1-1.5 h
Major painful procedures	Propofol (+ analgesic of choice)	IV: 1-2 mg/kg (repeat 0.5 mg/kg prn)	seconds	5-10 min
	Ketamine (+ midazolam)	IV: 1-2 mg/kg IM: 4-5 mg/kg	IV: 1-2 min IM: 3-5 min	IV: 15 min IM: 30-45 min

Abbreviations: IM, intramuscular; IN, intranasal; IV, intravenous; PO, per oss.
Data source: Stern J, Pozun A. Pediatric procedural sedation. [Updated 2022 Sep 6]. In: *StatPearls* [Internet]. StatPearls Publishing; 2022 Jan-. Updated September 6, 2022. Accessed January 26, 2023. https://www.ncbi.nlm.nih.gov/books/NBK572100/#_NBK572100_pubdet_

Table 11-5. Pediatric Pain Medication Options

Pain level	Medication	Dose
Mild	Acetaminophen	15 mg/kg (max 75 mg/kg/day or 4,000 mg/day)
	Ibuprofen	10 mg/kg (max 40 mg/kg/day or 2400 mg/day)
Moderate	Oxycodone	<6 mo: 0.05 mg/kg/dose q4-6h >6 mo: 0.1-0.2 mg/kg/dose q4-6h (max 5-10 mg/dose)
	Morphine (max 10-20 mg)	Enteral: 0.15-0.3 mg/kg/dose q3-4h
Severe	Morphine (max 2-5 mg)	Intravenous: 0.05-0.1 mg/kg/dose q2-4h
	Fentanyl	Intravenous: 0.5-1 mcg/kg/dose q1-2h (max 25-50 mcg) Intranasal: 2 mcg/kg x1 (max dose 100 mcg/dose)
	Hydromorphone (oral <1/2 as effective as IV) q3-6h (max 0.2-0.6 mg)	Enteral: 0.03-0.06 mg/kg/dose q4h (max 1-2 mg) Intravenous: 0.01-0.015 mg/kg/dose
	Ketamine, low-dose for pain	Intranasal: 0.2-1 mg/kg (max 40 mg/dose) may repeat once Intravenous: 0.1-0.3 mg/kg (max 25 mg for pain)

Data sources: O'Donnell FT, Rosen KR. Pediatric pain management: a review. *Mo Med*. 2014;111(3):231-7.

Greco C, Berde C. Pain management for the hospitalized pediatric patient. *Pediatr Clin North Am*. 2005;52(4):995-1027,vii-viii.

Berde CB, Sethna NF. Analgesics for the treatment of pain in children [published correction appears in *N Engl J Med*. 2011;364(18):1782]. *N Engl J Med*. 2002;347(14):1094-1103.

Oliveira J E Silva L, Lee JY, Bellolio F, Homme JL, Anderson JL. Intranasal ketamine for acute pain management in children: a systematic review and meta-analysis. *Am J Emerg Med*. 2020;38(9):1860-1866.

Fluids and Electrolytes

In austere environments, dehydration and electrolyte derangements are common and may be diagnosed based on clinical suspicion rather than laboratory studies. In austere settings with limited laboratory monitoring, avoiding iatrogenic electrolyte derangements that can occur with intravenous fluids is important. Treatment is mainly supportive.

- Assess the patient for dehydration (Table 11-6).
- Preferentially treat dehydration with oral rehydration solution (ORS).
- For patients who cannot take fluids by mouth or are in shock, first resuscitate with normal saline (NS) or lactated Ringers (LR) in 10 to 20 mL/kg aliquots, reassessing after each bolus.

Replace fluid losses and maintain sufficient fluids (Table 11-7). Figure 11-1 provides an ORS recipe from the World Health Organization.

Key points to consider:

- Without advanced diagnostics, it is safer to rehydrate and refeed children enterally rather than parenterally.

Table 11-6. Physical Exam Findings for Dehydration

	Dehydration		
Sign	**Mild**	**Moderate**	**Severe**
Behavior	Normal	Listless	Lethargic, confused
Mucous membranes	Normal	Dry	Dry
Fontanelle	Flat	Sunken	Sunken
Skin turgor	Normal	Decreased	Decreased
Blood pressure	Normal	Normal	Decreased
Heart rate	Normal	Increased	Increased
Urine output	Decreased	Decreased	Anuric

Data source: Meyers RS. Pediatric fluid and electrolyte therapy. *J Pediatr Pharmacol Ther*. 2009;14(4):204-211.

Table 11-7. Principles of Fluid and Electrolyte Management in Prolonged Care

	Minimum	Better	Best
Hydration (titrate based on output)	Oral		IV
Urine output (goal 1-2 mL/kg/h)	Collect and measure	Foley catheter	Foley catheter
Glucose and electrolytes	Symptom recognition	Point-of-care testing, blood gas	Serumelectrolytes
Treatments	Empiric enteral supplementation		IV replacement

Abbreviation: IV, intravenous.
Data source: Meyers RS. Pediatric fluid and electrolyte therapy. *J Pediatr Pharmacol Ther.* 2009;14(4):204-211.

Oral Rehydration Recipe (makes 1 L)

6 tsp table sugar
½ tsp table salt
½ tsp baking soda
¼ tsp potassium chloride (if available)
1 L clean water

Figure 11-1. The World Health Organization recipe for oral rehydration solution.

- It is safer to replace electrolytes by mouth in the absence of monitoring.
- Nasogastric feeding tubes can be placed to assist the administration if the patient cannot take oral medications, as would occur with respiratory insufficiency or decreased mental status.

Following resuscitation:

- Calculate maintenance fluid requirements (intravenous or oral) as shown in Table 11-8. For example, to calculate fluid delivery to a 45 kg child, apply the formula as follows—10 (4 mL/kg/h) + 10 (2 mL/kg/h) + 25 (1 mL/kg/h) = 85 mL/kg/h.
- D5 NS (with potassium chloride if there are no concerns for renal injury) is a typical choice for IV maintenance fluids, though this may not be available in austere settings.

Table 11-8. Maintenance Fluid Calculation

Child's weight (kg)	Rate of fluid delivery (mL/kg/h)
First 10	4
Second 10	2
Every kg above 20	1

Data source: Holliday MA, Segar WE. The maintenance need for water in parenteral fluid therapy. *Pediatrics.* 1957;19:823-832.

- If using only NS or LR, smaller children will require some dextrose supplementation. (5% dextrose should be sufficient).
- The color of urine may give clues about the hydration status.
- Consider other fluid losses (eg, vomiting, diarrhea, skin/burn insensible losses).

Diabetic Ketoacidosis

In the prolonged care setting, limitations in laboratory capabilities and availability of insulin will hamper the management of diabetic ketoacidosis (DKA). Stabilization and rapid transport out of the theater as soon as possible are essential, especially if insulin is not readily available. Consult a specialist as soon as possible to help with the nuances of the case.

Symptoms

- Weight loss.
- Polydipsia.

- Polyuria.
- Vomiting.
- Diaphoresis.
- Heavy, labored breathing.
- Altered mental status.

Treatment

Aim treatment at slowly correcting the acidosis and electrolyte abnormalities and resuscitating fluid losses (Tables 11-9 and 11-10).

Key points to consider:

- Careful fluid resuscitation is essential to avoid steep drops in serum osmoles, which put the patient at risk for cerebral edema.
- Consider intramuscular insulin (over IV) in resource-limited settings with insulin available, which will correct glucose at a slower, safer rate.
- If monitoring capabilities are limited, but transport is available, consider providing only basic rehydration and avoid using insulin until the patient is at a higher level of care.
- Total body potassium will be low, even if serum potassium is normal or elevated. Replacement is essential, especially if giving insulin. Do not give insulin if unable to provide potassium supplementation.

Humanitarian Care

The major causes of morbidity and deaths in refugee populations include malnutrition, respiratory infections, diarrhea and dehydration, measles, and malaria. Teams should prepare appropriately if engaged in these operations.

Severe Acute Malnutrition

Undernutrition is linked to nearly half of all deaths among children under five, mostly in low- and middle-income countries.[1] There are two types of severe acute malnutrition (SAM): marasmus (most common) and kwashiorkor (edematous malnutrition). Marasmus is caused by inadequate intake of calories and nutrients. It is characterized by low weight for

height with reduced mid-upper arm circumference (MUAC). Kwashiorkor (edematous malnutrition) is malnutrition due to inadequate protein intake. It is characterized by muscle atrophy and symmetric peripheral pitting edema, starting in dependent areas and proceeding cranially.

Identify Severe Acute Malnutrition. Fully evaluate infants and children ages 6 to 59 months with any of the following:

- Weight-for-height z-scores <3 standard deviations below the median.
- Those with MUAC <115 mm.
- Those who have any degree of bilateral edema.
- Inpatient infants and children who have:
  - Medical complications.
  - Severe edema (including feet, legs, hands, arms, and face).
  - Poor appetite.
  - Vomiting.
  - Convulsions.
  - Lethargy.

Treat Severe Acute Malnutrition. General guidelines for refeeding a patient with SAM include the following:

- Start reintroducing calories at around 10 to 20 kcal/kg for the first 24 hours, advancing by 33% every 1 to 2 days.
- If the patient is at high risk of refeeding syndrome, consider electrolyte repletion before reintroducing or escalating calories.
- Monitor vital signs closely.
- If available, initiate thiamine supplementation (100 mg/day) before refeeding and continue for 5 to 7 days.

Table 11-11 gives additional SAM management information.

Respiratory Infections

Most upper respiratory infections, as well as bronchiolitis, are due to viruses; avoid antibiotics. Lower respiratory infections are recognized as the leading cause of death globally in children under 5 years old and may need to be diagnosed empirically based on cough, tachypnea, and fever.

Table 11-9. Management of Diabetic Ketoacidosis

Capabilities	Labs	Fluids	Insulin
Minimum (insulin unavailable)	Initial: POC glucose Urine dipstick	Hour 1: NS or LR at 10-20 mL/kg Maintain hydration Avoid over-resuscitation	NA
Better (insulin available)	Initial: VBG POC glucose Urinalysis POC electrolytes monitoring POC glucose q1h Urinalysis until ketosis resolves POC electrolytes q4-6h Neuro checks q1-2h	Hour 1: NS or LR at 10-20 mL/kg Start NS/LR +KPhos or KCl Once blood sugar <300 mg/dL, add dextrose containing fluids (target blood sugar 150 mg/dL)	IM insulin 0.1-0.3 units/kg every 3 h (start low with limited lab capabilities) Do not give insulin if unable to give potassium supplementation Consider holding insulin if unable to monitor electrolytes

(**Table 11-9** *Continues*)

Table 11-9 *Continued*

Capabilities	Labs	Fluids	Insulin
Best (likely Role 3 capabilities)	Initial: VBG POC glucose Urinalysis Chemistry Calcium, magnesium, phosphorous monitoring POC glucose q1h VBG q4h Urinalysis until ketosis resolves Electrolytes q4h Neuro checks	Hour 1: NS or LR at 10-20 mL/kg Start NS/LR + KPhos or KCl Once blood sugar < 300 mg/dL, add dextrose containing fluids (target blood sugar 150 mg/dL)	Start insulin 0.05-0.1 units/kg/h (DO NOT use bolus IV insulin)

Abbreviations: IM, intramuscular; LR, lactated Ringer solution; NS, normal saline; POC, point of care; VBG, venous blood gas.
Data sources: Rosenbloom AL. The management of diabetic ketoacidosis in children. *Diabetes Ther*. 2010;1(2):103-120.
Creamer KM, Fuenfer MA. *Pediatric Surgery and Medicine for Hostile Environments,* 2nd ed. Borden Institute; 2016.

Table 11-10. Management of Electrolyte Derangements

Electrolyte abnormality	History	Symptoms	Treatment	
			Minimum	Better (with lab capabilities)
Hypoglycemia	Stress Cold exposure Infection Iatrogenic	AMS Seizures	Enteral fluids containing sugar	1 mL/kg D50 (central or IO) or 2 mL/kg of D25. Infants: 5 mL/kg D10W may be administered If adrenal insufficiency is suspected, administer hydrocortisone by age: ◦ 0-3 y, 25 mg ◦ 3-12 y, 50 mg ◦ >12 y, 100 mg
Hypernatremia	Dehydration Vomiting Diarrhea DI	AMS Seizures Lethargy	Oral isotonic fluids For DI, replace urine output orally or rectally with free water	IV fluids: D5 1/2NS at 1.5 × maintenance Correct slowly over 24 h For DI: vasopressin 0.5 millU/kg/h
Hyponatremia	GI losses Hypotonic fluid resuscitation	AMS Poor feeding Lethargy	ORS If SIADH, restrict fluids	If seizures: ◦ 3% saline 1 mL/kg, repeat until seizures stop

(**Table 11-10** *Continues*)

Table 11-10 *Continues*

Electrolyte abnormality	History	Symptoms	Treatment	
			Minimum	**Better (with lab capabilities)**
Hyponatremia (cont.)	CF SIADH	Vomiting Seizures		◦ correct slowly over 24 h
Hyperkalemia	Potassium (K) containing fluids Rhabdomyolysis Tumor lysis Metabolic (DKA) acidosis	Present with K >7 mEq/L: ◦ weakness ◦ paralysis ◦ arrhythmias	Calcium gluconate (10%) 50-100 mg/kg IV or calcium chloride 20 mg/kg IV Albuterol Sodium polystyrene sulfonate 1 g/kg orally or rectally q6h	Calcium gluconate or calcium chloride IV Fluid bolus and Furosemide 0.5-1 mg/kg IV Insulin 0.1 U/kg (max 10 U) mixed with dextrose 0.5 g/kg/dose ◦ Child <5, give D10 at 5 ml/kg ◦ Child 5 or older, give D25 at 2 mL/kg
Hypokalemia	Malnutrition Diarrhea Vomiting Albuterol Insulin	Weakness Paralysis Arrhythmia Polyuria	Oral K supplementation 1-3 mEq/kg/d div q6-8h	If severe: <2. 5 mEq/L IV replacement 0.5-1 mEq/kg/dose over several hours (DO NOT PUSH) Need telemetry

(**Table 11-10** *Continues*)

Table 11-10 *Continued*

Electrolyte abnormality	History	Symptoms	Treatment	
			Minimum	**Better (with lab capabilities)**
Hypocalcemia	Blood transfusion Malnutrition Genetic disorders	Tetany Fatigue Paresthesia Trousseau sign Chvostek sign Bronchospasm Heart failure	Oral calcium supplementation 30-75 mg elemental/kg/d divided TID	Calcium gluconate (10%) 50-100 mg/kg IV Calcium chloride 20 mg/kg IV
Hypomagnesemia	Malnutrition, Malabsorption	Fatigue Paresthesia Dysrhythmia	Oral-elemental magnesium 10-20 mg/kg/dose up to 4× daily	25-50 mg/kg IV over 3-4 h
Hypophosphatemia	Malnutrition Malabsorption	Fatigue Paresthesia Dysrhythmia	Oral potassium or sodium phosphate (consider prior to choosing supplement) 2-3 mmol/kg/d divided in 4 doses	Sodium or potassium phosphate 0.16-0.32 mg/kg over 4 h

(**Table 11-10** *Continues*)

Table 11-10 *Continued*

Electrolyte abnormality	History	Symptoms	Treatment	
			Minimum	**Better (with lab capabilities)**
Thiamine deficiency	Common in refeeding syndrome. Can be seen in infants of mothers with deficient diets	Dry beriberi ◦ neuropathy ◦ AMS ◦ seizures Wet beriberi ◦ cardiac failure ◦ edema ◦ pulmonary ◦ congestion	Empiric thiamine supplementation 100 mg/d before refeeding	IV or IM 50-100 mg for several days Follow with PO supplementation of 200 mg/d for several weeks

Abbreviations: AMS, altered mental status; CF, cystic fibrosis; DI, diabetes insipidus; DKA, diabetic ketoacidosis; GI, gastrointestinal; IM, intramuscular; IO, intraosseous; IV, intravenous; ORS, oral rehydration solution; PO, per os; SIADH, syndrome of inappropriate anti-diuretic hormone; TID, three times per day.

Data sources: Society of Critical Care Medicine. Critical care in infants and children with limited resources in austere environments: the basics. In: Pamplin JC, Borgman MA. *Fundamental Critical Care Support: Resource Limited: Delivery of Care in Austere and Operational Environments*. Society of Critical Care Medicine; 2020:chap 13.

Evans IVR, Joyce EL. Fluid and electrolyte issues in pediatric critical illness. In: Zimmerman JJ, Rotta AT, eds. *Fuhrman and Zimmerman's Pediatric Critical Care*. 6th ed. Elsevier; 2021:866-881.

Bauer A, Jones S, Sullivan C. Recognition and management of malnutrition. In: Hickey P, ed. *Military Medical Humanitarian Assistance Course Manual.* USUHS CGHE; 2016:66-111.

Pulcini CD, Zettle S, Srinath A. Refeeding syndrome. *Pediatr Rev.* 2016;37(12):516-523. https://doi.org/10.1542/pir.2015-0152

Table 11-11. Management of Severe Acute Malnutrition in Children

	Minimum	Better	Comments
Diet	MRE/Local food: follow caloric guidelines and electrolyte supplementation[a]	F-75, F-100, ready to-use therapeutic food blends: ◦ start with F-75 ◦ slowly titrate up over several days	
Fluids	Locally prepared solution ◦ WHO ORS[b] ◦ dissolve in 2 L water (instead of 1 L) at 5-10 mL/kg/h for up to 12 h	ReSoMal (ORS exclusively for severely malnourished)	If in shock: ◦ resuscitate with 15 mL/kg/h with D5LR or D5½NS ◦ if not improved, transfuse 10 mL/kg of PRBCs over 3 h If profuse watery diarrhea or cholera, WHO ORS is acceptable
Electrolytes	Empiric enteral replacement of ◦ potassium ◦ magnesium ◦ phosphate ◦ thiamine	Laboratory evaluation and monitoring Enteral repletion Cardiac monitoring IV replacement if severe[a]	Refeeding Syndrome: ◦ Occurs with rapid refeeding ◦ carbohydrates trigger uptake of phosphate potassium magnesium

(**Table 11-11** *Continues*)

Table 11-11 *Continued*

Minimum	Better	Comments
Electrolytes (cont.)		○ Resulting in system dysfunctions ▫ cardiac ▫ respiratory ▫ neurologic
Antibiotics		SAM plus complications: IV antibiotics SAM with no evidence of infection: oral antibiotics (amoxicillin)

Abbreviations: D5LR, 5% dextrose lactated Ringer solution; F-100, Formula 100; F-75, Formula 75; IV, intravenous; MRE, Meals, Ready-to-Eat; NS, normal saline; ORS, oral rehydration solution; PRBCs, packed red blood cells; ReSoMal, rehydration solution for malnutrition; SAM, severe acute malnutrition; WHO, World Health Organization.

[a] Table 11-10

[b] Figure 11-1

Data source: World Health Organization. Updates on the management of SAM in infants and children. World Health Organization website. Updated August 2013. Accessed February 8, 2023. https://www.who.int/publications/i/item/9789241506328

Viral Bronchiolitis. Treatment is mainly supportive. Generally, treat hypoxia, hypercarbia, and dehydration.

- Respiratory support can come from a high-flow nasal cannula (HFNC) at 1.5 to 2 L/kg/min.
- Approximately 10% of patients require intubation even after starting HFNC.
- Failure to improve, tachycardia, and tachypnea are indicators to escalate therapy, intubate, or transfer, when possible, to a higher echelon of care.
- Consider bronchodilators, such as racemic epinephrine and inhaled albuterol, in patients with worsening respiratory failure.
- Corticosteroids are not indicated but may be considered.
- Hydration is essential; children with respiratory distress are often dehydrated.
  - Provide fluids by either nasogastric tube or intravenously, depending on the facility's capabilities.
  - Carefully consider enteral feeding in patients at risk for intubation.

Lower Respiratory Infections.

- Diagnose pneumonia by coughing, tachypnea (with or without fever), and diminished breath sounds.
- Tachypnea is highly sensitive to the severity of the disease.
- Amoxicillin should cover most cases of pneumonia; for severe pneumonia, consider ceftriaxone or a similar 3rd generation cephalosporin.

Asthma

Asthma is the most common chronic disease among children, with deaths mainly happening in low- and middle-income countries due to inadequate diagnoses and treatment.[2] Prolonged care providers should be prepared for the presentation and management of asthma, including status asthmaticus.

Signs and symptoms of asthma include:

- Diffuse, polyphonic wheezing.
- Cough.
- Tachypnea.
- Retractions.

- Nasal flaring.
- Speaking in short sentences.

Consider treatments in Table 11-12 until the work of breathing and wheezing improve. Reassess the patient every 20 minutes initially until stabilized. Escalate care as needed.

Measles

Measles is a highly contagious, acute, febrile viral illness. Although vaccination resulted in a 73% drop in measles worldwide between 2000 and 2018, measles still caused approximately 140,000 deaths in 2018, mostly in children under five.[3] Mortality can occur from superimposed bacterial infections.

Table 11-12. Management of Acute Asthma Exacerbation

	Treatment	
Medication	**Mild**	**Moderate to severe**
Albuterol	Nebulized 2.5-5 mg or 4-8 puffs (MDI)	Continuous nebulizer 0.6 mg/kg/h (10-40 mg/h)
Ipratropium	Nebulized 0.5 mg	Scheduled nebulization q4-6h
Steroids (to decrease inflammatory response)	Consider	Give oral or IV (as available) ◦ dexamethasone 0.6 mg/kg ◦ prednisone 1 mg/kg ◦ hydrocortisone 50 mg ◦ methylprednisolone 1 mg/kg (max 60 mg)
Magnesium sulfate	50 mg/kg over 20 min (max 2g)	Can schedule q6h
Epinephrine		0.1 mg/kg (1:1000) SQ, can repeat in 15 min if no response
Oxygen supplementation	If applicable	If applicable

Abbreviations: IV, intravenous; MDI, metered dose inhaler; SQ, subcutaneous.
Data source: Saharan S, Lodha R, Kabra SK. Management of status asthmaticus in children. *Indian J Pediatr*. 2010;77:1417-1423.

Signs and symptoms of measles include the following:

- Fever.
- Maculopapular rash.
  - Typically follows the fever by a few days.
  - Spreads from the face and head to the trunk.
- Classical "three Cs" of measles.
  - Cough.
  - Coryza.
  - Conjunctivitis.
- Small white papules (Koplik spots) appear a few days before the rash.

Management of measles is supportive, with the addition of vitamin A for two days (by age) as follows:

- Under 6 months: 50,000 IU.
- 6 to 12 months: 100,000 IU.
- >12 months: 200,000 IU.

Give a third dose of vitamin A 2 to 4 weeks later with evidence of deficiency.

Note: Maintain a low threshold for starting antibiotics for superimposed infections.

Recovery takes approximately a week. Complications can occur in young infants and malnourished and immunocompromised individuals. Complications include:

- Pneumonia.
- Croup.
- Otitis media.
- Diarrhea.
- Blindness.
- Acute disseminated encephalomyelitis.
- Inclusion body encephalitis.
- Subacute sclerosing panencephalitis.

Malaria

Malaria is widespread in tropical and subtropical areas worldwide, causing about 619,000 deaths in 2021.[4] Most deaths

occur in children under 5 years old. Understand the prevalent species and resistance patterns in the prolonged care area of operations. Recognition of severe disease is essential. Rapid treatment with IV antimalarial medication and transfer to a higher level of care are vital.

Signs and symptoms of uncomplicated malaria include the following:

- Fever.
- Chills.
- Headache.
- Myalgia.
- Diarrhea.
- Mild to moderate anemia.

Signs and symptoms of severe malaria (commonly caused by *Plasmodium falciparum*) include the following:

- Conjunctival pallor.
- Tachypnea from acidosis or pulmonary edema.
- Tachycardia from severe anemia.
- Shock.
- Splenomegaly.
- Altered mental status.
- Seizures.
- Hypoglycemia.
- Renal failure.

In children, fever with nausea, vomiting, and diarrhea are common.

Note: The classic cyclical fever does not commonly occur early in malaria infection.

Evaluate for malaria using:

- Blood smear (thick and thin).
- Complete blood count.
- Chemistry panel.
- Urinalysis.
- Lumbar puncture.

Table 11-13. Treatment of Diarrheal Illness

Disease	Symptoms	Treatment[a]	Comments
Cholera	Clear or rice-watery diarrhea Cramps Weakness Thirst Mild fever Mild abdominal pain	Doxycycline 6 mg/kg PO × 1 (max 300 mg) Erythromycin 12.5 mg/kg PO q6h × 3 d Azithromycin 20 mg/kg (max 1 g) PO × 1	Can progress to shock rapidly within 12 h in severe cases
Dysentery (bacillary)—most often shigellosis	Acute onset diarrhea (initial watery) with transition to blood and mucus Tenesmus Vomiting Fever Seizures	Ciprofloxacin (15 mg/kg PO BID × 3 d [max 500 mg]) Ceftriaxone 50-100 mg/kg/day IM for 2-5 d Azithromycin 10 mg/kg PO daily × 3 or 20 mg/kg PO x 1	
Dysentery (amoebic)	Gradual onset Abdominal pain Blood Fever	Metronidazole 10 mg/kg TID × 5-10 d	Most severe in ◦ infants ◦ pregnant ◦ malnourished

(**Table 11-13** *Continues*)

Table 11-13 *Continued*

Disease	Symptoms	Treatment[a]	Comments
Dysentery (amoebic) (cont.)	Hepatomegaly		Consider if two treatments for shigella fail
Giardiasis	Diarrhea ◦ non-bloody ◦ profuse ◦ foul smelling Abdominal cramps Flatulence	Metronidazole 5-10 mg/kg TID × 5 d	Fever is rare

Abbreviations: BID, two times per day; PO, per os; TID, three times per day.

[a] Zinc supplementation (20 mg/d for 10-14 d) decreases mortality and hospitalization in diarrheal illness.

Data sources: Bercu TE, Petri WA, Behm JW. Amebic colitis: new insights into pathogenesis and treatment. *Curr Gastroenterol Rep*. 2007;9:429.
Bradley JS, Nelson JD, Barnett ED, Cantey JB, eds. *Nelson's Pediatric Antimicrobial Therapy*. 24th ed. American Academy of Pediatrics; 2018.
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Islam MS, Midzi SM, Charimari L, et al. Susceptibility to fluoroquinolones of Vibrio cholerae O1 isolated from diarrheal patients in Zimbabwe. *JAMA*. 2009;302(21):2321–2322.
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Yamamoto T, Nair GB, Albert MJ, et al. Survey of in vitro susceptibilities of *Vibrio cholerae* O1 and O139 to antimicrobial agents. *Antimicrob Agents Chemother*. 1995;39(1):241–244.

- Blood cultures.
- Blood gas.
- Blood type and cross match.

Treat malaria as follows:

- IV artesunate, 2.4 mg/kg at hours 0, 12, and 24 (first-line treatment for severe malaria).
- Oral antimalarial medication for uncomplicated malaria or if artesunate is not available. Give via a nasogastric tube if oral intake is not tolerated.
  - Artemether-lumefantrine.
  - Atovaquone-proguanil.
  - Quinine sulfate.
  - Mefloquine.
  - Doxycycline.
- The World Health Organization recommends blood transfusions, which can be given at 20 to 30 mL/kg volumes over 3 to 4 hours.

Caution: Studies show worse outcomes in children who received fluid boluses. Concern for hemodilution, reperfusion injury, worsening cerebral edema, and acidosis may contribute.

Diarrhea and Dehydration

Acute gastroenteritis (AGE) is the second leading cause of death worldwide due to infections among children under 5 years old.[5] Antibiotics are not indicated in most diarrhea cases as the etiology is often viral, and management is supportive with fluid resuscitation. Consider antibiotics or antimalarial therapy only in specific cases. Treat diarrheal illnesses as detailed in Table 11-13.

Summary

The following resources provide additional information for prolonged care providers:

- Creamer KM, Fuenfer MA. *Pediatric Surgery and Medicine for Hostile Environments*, 2nd ed. Borden Institute. 2016.
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2. Asthma. World Health Organization website. Published May 11, 2022. Accessed January 26, 2023. https://www.who.int/news-room/fact-sheets/detail/asthma

3. Measles. World Health Organization website. Published December 5, 2019. Accessed January 26, 2023. https://www.who.int/news-room/fact-sheets/detail/measles

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Chapter 12

NUTRITION

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Introduction

Traditionally, patient feeding occurs at Role 3 and Role 4, and rapid evacuation of casualties allows for early initiation of enteral nutrition. Army field feeding regulations mandate three hot, prepared meals and any medically indicated nourishment for all hospitalized patients. In contrast to traditional hospital-based nutrition care operations, a prolonged care (PC) environment may necessitate initiating medical nutrition therapy at more forward locations. Prolonged patient holding requires field medical care, including nutrition assessments, diagnoses, interventions, and monitoring. In this environment, gaps in training, skill, doctrine, and resources present a challenge for nutrition support in field medical care.

Key Principles

- Start nutrition interventions as soon as possible to support the immune system and hasten recovery from injury or illness.
- Use energy estimates appropriate for reference body size to improve nutrition interventions.
- Monitor and document individual nutrition interventions.
- Familiarize with available food items, diet types, and nutrition resources to improve response while operating in a PC environment.
- Incorporate PC nutrition during routine training to optimize the delivery and efficiency of nutrition on the battlefield.
- Consult with nutrition specialists when possible. They can help determine feeding goals, food types, feeding schedules, and feeding methods.

Nutrients and Their Functions

The human body requires a continual and sufficient supply of macronutrients and micronutrients to maintain physiological functions. Macronutrients (carbohydrates, fats, and proteins) supply food energy, measured in calories. In most scenarios, carbohydrates are the preferred energy source, and fat is the primary stored energy source. Protein is not typically used as an energy source due to its role in the structure and function of the body. However, protein is broken down for energy in circumstances such as starvation, insufficient energy intake, prolonged physical exertion, and severe illness or injury.[1]

Micronutrients (vitamins, major minerals, and trace minerals) are not a source of energy; the human body uses them in smaller quantities than macronutrients. Vitamins and minerals support metabolism, muscles, growth, and reproductive and immune functions. Consuming an inadequate amount of any micronutrient can disrupt essential physiological functions. During critical illness or following injury, micronutrient needs increase due to increased metabolic demands and requirements for healing. At a minimum, nutrition intervention for critically ill patients should include the daily reference intakes (DRIs) for vitamins and minerals, mostly met with a standard, complete multivitamin or approximately 1000 mL of standard tube-feeding formula.[1]

A dietary pattern within the recommended daily energy limits that includes nutrient-dense food and beverages across all food groups is most appropriate for general health.[2] Service members may have increased energy and nutrient demands based on the unique mission requirements and environmental factors. For this reason, military dietary reference intakes (MDRIs) establish the minimum requirements for military feeding and operational rations.[3] For reference, each complete Meal, Ready-to-Eat (MRE) provides an average of 1250 kcal (13% protein, 36% fat, and 51% carbohydrate) and 33% of the MDRIs of vitamins and minerals.

Challenges of Providing Nutrition During Prolonged Care

Medical nutrition therapy includes initial assessment, nutrition diagnosis, individualized intervention, periodic monitoring and evaluation, and reassessment. The goal of nutrition intervention is to help an individual recover and return to the fight or recover and rehabilitate to a new normal of life. Early and appropriate nutrition allows patients to progress through the recovery and rehabilitation process as quickly as possible.

Delayed Evacuation

A large-scale conflict resulting in delayed evacuation and increased patient hold time presents many challenges for the adequate and appropriate delivery of nutrition. Delayed evacuation from Role 1, Role 2, and other non-doctrinal patient holding locations will likely create the need for nutrition intervention where dietitians and nutrition care specialists are not traditionally located. Ensuring patients' nutritional needs may be new and overwhelming for the combat medic, corpsman, or other emergency medical providers accustomed to the rapid evacuation of trauma patients.

Personnel

Lack of readily available, trained nutrition professionals coupled with limited staffing may result in tasks not considered of high importance falling to the wayside. Nutrition care and many other patient-holding tasks are unfamiliar to many Role 1 providers. In an environment where medical providers are overwhelmed with high patient volume and are at risk of burn out, patient feeding may be overlooked or not prioritized.

Even when conditions support patient feeding, it may be challenging for inexperienced medical providers to know where to begin. Due to the lack of resources and confidence, providers may be apprehensive about patient feeding despite their best intentions. Additionally, providers may struggle to choose the most appropriate intervention or nutrition prescription when managing patients who require modified diets or who cannot receive nutrition orally.

Logistics

Locations fortunate enough to have the workforce, skill, and opportunity to support patient feeding may still be constrained by supply shortages and other environmental challenges. Limited food and ration supply may put service members in a nutritionally compromised status regardless of injury or illness. Also, supplies traditionally used for patient feeding (eg, therapeutic meal kits, tubes, blenders, supplements) may not be readily available or usable in austere locations. Additionally, administering nutrition at these locations may not be feasible as the site may not have the workspace or materials necessary to support proper sanitation and cleanliness.

Administrative Requirements

Finally, gaps in patient documentation may also present a barrier to initiating and maintaining nutrition. Patients may arrive at military treatment facilities with missing or damaged records during a large-scale conflict. Lack of documentation and subsequent uncertainty about previously administered medications, indicators of gut motility, or organ function can cause feeding to be delayed or withheld. During patient holding, the administrative burden of handwritten documentation could lead to errors and intervention gaps. For nutrition care, incomplete or absent documentation for feeding volumes, start and stop times, and fluid status can cause inaccurate feeding and poor patient outcomes.

Critically Ill Casualties

Critically ill casualties must receive early nutrition intervention, which can be difficult in PC settings. Nutrition interventions support immune function, maintain gastrointestinal integrity and function, and are most effective when employed early. When feasible, nutrition interventions should be implemented within 24 to 48 hours after injury or critical illness via the oral or enteral route.[4] Critically ill patients are those who have any of the following[1]:

- Blunt or penetrating trauma.
- Significant wounds.

- >20% total body surface area (TBSA) burn.
- Illness (pneumonia).
- Sepsis.
- A hypermetabolic or hypercatabolic state driven by an inflammatory response.

A hypermetabolic response and an increased inflammatory response may lead to organ failure, and a hypercatabolic state leads to a breakdown in muscle protein.[5] Providing nutrition can attenuate this response and improve patient outcomes.

Energy Requirements

Standards

Estimated energy requirements are equation based and account for several factors impacting daily energy expenditure. Estimated energy requirements are more precise with accurate anthropometric data. However, obtaining actual height and weight may be complicated by other factors associated with critical illness, such as edema, amputation, and fluid resuscitation. Real anthropometric data may also be unattainable in the setting of PC due to time and resource constraints. A practical approach to estimate energy requirements is to use service member reference body sizes. Army Regulation 40-25, Nutrition and Menu Standards for Human Performance Optimization, defines body size using height and weight reference measures[3]:

- Reference measures for military men are a height of 69 in. (175 cm) and a weight of 187 lb (85 kg).
- Reference measures for military women are a height of 64 in. (163 cm) and a weight of 152 lb (69 kg).

Using the reference weight of 85 kg for males or 69 kg for females as a simplistic weight-based equation is appropriate to determine energy requirements. Current trauma guidelines estimate energy requirements at 20 to 35 kcal/kg. However, given that the military population is generally younger, healthier, and likely to have multiple traumatic injuries, total energy requirements are estimated at 30 to 35 kcal/kg.[4]

Table 12-1. Nutrient Functions and Sources

Nutrient	Function	Sources		
		Dining facility or commercial items	**Individual operational rations (MRE, FSR, MORE)**	**Unitized group ration – heat and serve (UGR)**
Protein	Build and maintain tissue; regulate water balance; form hormones, enzymes, and antibodies; excess intake used as energy	Meat, fish, cheese, milk, poultry, eggs, whole grains, nuts, beans	Entrées, sandwiches, cheese, peanut butter, beans, beef snack, chocolate protein drink, turkey snacks	Beef, chicken, turkey, meatballs, chili, eggs, sausage links, milk, beans
Carbohydrate	Primary energy source; dietary fiber (nondigestible carbohydrate) assists the digestive system	Breads, pasta, starchy vegetables, fruits, juices	Tortilla, crackers, fruits, cocoa, jelly, carbohydrate beverage base, applesauce, toaster pastry, breadsticks, First Strike bar, pudding, cocoa beverage powder	Grits, pasta, oatmeal, jam, vegetables, rice, canned fruit, tortilla, cornbread, mashed potatoes, juice

(**Table 12-1** *Continues*)

Table 12-1 *Continued*

Nutrient	Function	Sources		
		Dining facility or commercial items	**Individual operational rations (MRE, FSR, MORE)**	**Unitized group ration – heat and serve (UGR)**
Fat	Provide energy; supply fatty acids for cell membranes; absorption of fat-soluble vitamins	Oils, butter, cheese, nuts, margarine, salad dressings	Peanut butter, entrées, cheese, trail mix, nuts	Peanut butter, milk, dressings
Water	Transport vital substances throughout the body; regulate normal body temperature	Beverages of any kind, foods with high water content (especially fresh fruits and vegetables)	Beverages, entrées, wet-packed fruits	Beverages, entrées, fruits

Abbreviations: FSR, First Strike Ration; MORE, Modular Operational Ration Enhancement; MRE, Meal, Ready-to-Eat.

Requirements for Critically Ill and Trauma Patients

For critically ill and trauma patients, there are over 20 different factors that influence energy needs. The most critical factors in PC settings include the following:

- Age.
- Sex.
- Type of injury.
- Severity of injury.
- Body composition.
- Nutrition status before injury.
- Concurrent infection or illness.

In a PC environment, injured or ill patients may present with an altered physiological response, resulting in increased energy demands and an accelerated muscle mass breakdown. Increased metabolism and protein utilization may vary in duration and severity based on the nature of the critical illness or injury but are seen in patients with[6]:

- Sepsis, at approximately 120% of normal metabolism, for approximately 1 to 2 weeks.
- Surgery, at approximately 120% of normal metabolism for approximately 30 days.
- Minor trauma, at 120% of normal metabolism for 30 days.
- Major trauma, at 160% of normal metabolism for 60 days.
- Burn, at 180% to 200% of normal metabolism for 60 days, with prolonged hypermetabolism at 120% to 140% of normal metabolism for up to 3 years.

Therefore, during illness or following injury, a dietary pattern that includes higher total energy intake, especially from carbohydrates and proteins, is most supportive for healing and the recovery process. Food items to support nutrient needs may be procured from various sources, and typical examples are shown in Table 12-1. If available, consult a dietitian or other nutrition professional to assist with effective nutrition intervention plans.

Early Nutrition Intervention

Early nutrition therapy, within 24 to 48 hours of injury, has the following beneficial effects[6]:

- Attenuates the hypermetabolic response.
- Supports the immune system.
- Ensures casualties retain sufficient lean body mass and total body weight to support recovery and preserve physiologic functions.
- Shortens hospital stays.
- Improves survivability.
- Facilitates return to optimal function after injury.

Patients can lose significant body weight and muscle mass without nutrition intervention, resulting in functional impairment. Such impairments may include compromise of the immune system with decreased ability to fight infection, prolong the hospital stay, and eventually death.[1,7] Lean body mass losses during the initial phases after injury or illness will likely be restored once the patient is healthy and stable enough to participate in rehabilitative care. Once muscle tissue is broken down and used for energy, it is gone for the short term. A delayed nutrition intervention may prevent further lean muscle loss. Still, intervention will not restore the muscle used to fuel the patient during their initial injury period when nutrition was unavailable.

Early feeding helps patients achieve the calorie and protein intake needed to meet the estimated energy requirements described above. For casualties, especially those critically ill, early nutrition can help mitigate the effects of malnutrition and promote a faster recovery.[5] However, consider the risk of feeding an already malnourished patient who may suffer electrolyte abnormalities common in refeeding syndrome.

Early nutrition intervention utilizing the gastrointestinal (GI) tract protects the gut barrier, preventing bacteria from translocating from the GI system to the bloodstream, where they may cause sepsis. It also supports immune cell generation through gut-associated lymphoid tissue.

When to Feed Patients

Oral nutrition is often uncommon in critically ill patients but is the preferred feeding route if possible. If patients can eat or drink independently, encourage them to consume food and supplements as soon as they are stabilized. However, monitor these patients for nausea, vomiting, chewing, and swallowing difficulty. Patients in great pain may have a reduced or non-existent appetite. In these situations, providing concentrated calories and high-protein supplements is beneficial. Aim to provide alert and oriented patients with enough nutrition to yield 30 to 35 kcal/kg of the reference body size. Using the reference body sizes above, this equates to the following daily requirements:

- Male service members: 2550 to 2975 calories per day.
- Female service members: 2070 to 2415 calories per day.

Use the following guidance to determine when to feed patients:

- To start nutrition, a stable patient has the following states:
  - A secure airway.
  - Fluid resuscitated.
  - Hemodynamic stability.
  - Adequate gut perfusion.
  - No trauma to the GI tract.
- For patients with an orogastric (OG) or nasogastric (NG) tube, initiate enteral nutrition as soon as patients are hemodynamically stable.
- Withhold supplements and enteral nutrition 8 hours before surgery.
- If you initially estimate holding a patient for 12 hours but still have them in your care after 48 hours, see Table 12-2 and follow the feeding recommendations associated with the hold time.

Note: Evaluate facial trauma on a case-by-case basis. Placing an OG or NG tube in a patient with facial fractures risks further damage.

Table 12-2. Enteral Feeding Initiation Algorithm

Anticipated hold time (hours)	Patient condition	Alert and oriented	Chewing or swallowing difficulty (swallow risk screening results?)	Intervention
4-6	Burn, stable	Yes	No	Provide and maximize intake of regular diet and protein supplements Limit fluids to milk, ORS, and high-calorie supplements
4-6	Burn, stable	No	Unable to assess	Place NG or OG tube and initiate enteral nutrition to achieve full goal rate
0-12	Stable	Yes	No	Allow PO intake, regular diet, regular fluids
	Stable	No	Maybe	Can allow fluids and supplements if patient passes swallow risk screening
	Unstable	No	Unable to assess	No intervention
24	Stable	No	Yes, or unable to assess	Place NG or OG tube and initiate enteral feeding at 20-40 mL/h
48	Stable	No	Yes, or unable to assess	Place NG or OG tube and initiate enteral nutrition to achieve 50% of goal rate
24-48	Critically injured or ill, but stable	Yes	Yes, but not eating	If patient is not eating or drinking, initiate enteral feeding via NG or OG tube to achieve full goal rate
72+	Stable	No	Yes, or unable to assess	Place NG or OG tube and initiate enteral feeding to achieve full goal rate

Abbreviations: NG, nasogastric; OG, orogastric; ORS, oral rehydration solution; PO, per os.

Disruptions in Feeding

In the PC environment, nutrition interventions and therapeutic diets are frequently suspended for transport or procedures. It is imperative to start feeding early to fortify the casualty if feeding disruptions occur. Early support is always recommended, regardless of potential disruptions.

Feeding Goal Options

Despite various challenges, familiarization with acceptable methods and solutions can reduce the barriers to providing early nutrition care during PC. When supporting patients with enteral nutrition, the estimated energy requirement of 30 to 35 kcal/kg of reference body size generates the following enteral formula volume rates:

- Male service members: 130 to 150 mL of a 1 cal/mL formula per hour.
- Female service members: 105 to 120 mL of a 1 cal/mL formula per hour.

These estimates are based on a 20-hour feeding schedule that accounts for frequent interruptions and holds to enteral feeding. When ideal interventions in a PC setting are not feasible, the following options are acceptable:

- ***Good***: 20 to 40 mL/h to support the GI tract and immune function.
- ***Better:*** >50% of the defined feeding volume per hour.
- ***Best:*** 100% of the defined feeding volume per hour.

What to Feed Patients

Diet Types

Common beneficial nutrition interventions include regular rations and nutrition supplements (preferred for all casualties to provide energy and promote healing), texture-modified foods, and liquid diets.

- Texture-modified diets refer to soft, smashed, or pureed foods and beverages thickened to various levels of consistency. This diet helps patients with chewing or swallowing problems who

risk aspirating on food and fluids. Texture-modified diets are helpful for a fatigued patient to decrease the energy spent chewing and swallowing and to maximize caloric intake. Examples of texture-modified diets include the following:

- *Soft & bite-sized* refers to pieces of food no larger than 1.5 × 1.5 cm easily mashed with a fork. This modification helps patients who cannot bite off pieces of food but can chew and swallow. Examples include shredded tender meats, flaky fish, soft fruits such as oranges, and fully cooked vegetables.
- *Minced & moist* refers to soft food pieces that require minimal chewing. Examples include cooked rice, soft ground meats in a thick gravy, cooked vegetables, and softened mashed bananas.
- *Pureed* refers to foods that do not require biting or chewing and can be eaten with a spoon. Examples include applesauce and mashed potatoes. Most foods at this level must be blended to substitute for the lack of chewing ability.
- *Thickened liquids* help the patient better control liquids within their mouth. When swallowing, the rate of the fluid moving into the pharynx is slowed, which is thought to allow more time for the airway to close and prevent aspiration from liquid entering the airway. Commercial products exist to thicken beverages but likely will not be easily accessible. Thicken beverages with baby cereal, instant potato flakes, banana flakes, corn starch slurry, pureed food, and blended fruit.

Two types of liquid diets are used when the patient cannot chew or ingest texture-modified foods.

- Clear liquid diets refer to fluids you can see through, such as water, juice, broths, sodas, popsicles, and commercial supplement beverages.
  - Clear liquids are not nutritionally complete because they do not supply sufficient calories, protein, or micronutrients.
  - Use them only for short durations.
  - Progress to a minimum of full liquids as quickly as possible to better meet nutritional needs.

  - Full liquids are beverages and foods liquid at room temperature, such as milk, milkshakes, strained cream or thin pureed soups, and commercial nutrition supplements.
- The medical diet field feeding supplement provides the necessary items to support a complete liquid diet, such as liquid supplements, creamed soups, and powdered instant breakfast packets for mixing (Table 12-3).

Table 12-3. Contents of Each Medical Diet Field Feeding Supplement

Item	Case quantity	Total of each item
Instant breakfast, assorted flavors	9	540
Beef broth, dehydrated, regular	2	192
Chicken broth, dehydrated, regular	2	192
Cream chicken soup, condensed	1	48
Cream tomato soup, condensed	1	48
Gelatins, individual dessert cup		
Strawberry		
Strawberry/orange	3	144
Gatorade, lemon-lime	1	384
Ensure, 8 oz. liquid can		
chocolate plus		
vanilla plus	2	48
Sugar packet	1	1200
Sandwich bags	1	600
Plastic spoons	1	1200
Straws, flexible, individually wrapped	1	1000
8 oz. hot cups	1	1000
Cup lids with straw hole	1	1000

Adapted from US Army. *Army Field Feeding and Class I Operations*. DA; 2015. ATP 4-41, Table 4-3.

- The medical diet feeding supplements are typically used at Role 3. Access for more forward operating locations is based on supply chain availability and resupply coordination.

Supplements

Supplements can be premade commercial products (provided in the medical diet field feeding supplement) or made by adding nutrients to foods and beverages. For example, mix instant breakfast (from the medical diet field feeding supplement) with ultra-high-temperature milk from a field ration. Supplements are intended to be calorie- and nutrient-dense to optimize nutrition. Add the following to fortify foods and beverages to increase the density of nutrients:

- Protein.
  - A simple, unflavored whey protein supplement can be provided in a dosage of 25 g, no sooner than every 3 to 4 hours.
  - Add unflavored whey to any fluid or solid food, sweet or savory, where it can be dissolved (eg, juices, milk, applesauce, mashed potatoes, and soup). It will add a creamy texture to a food or beverage item, like regular milk or cream.

Note: For tube-fed patients, the 25 g of protein can be mixed with 100 mL of water and provided via a syringe down the feeding tube. Ensure you flush with at least 30 mL of water before and after delivery.

- Electrolytes.
  - Electrolytes can be affected by diarrhea and dehydration.
    - Hyperosmolar fluids can exacerbate diarrhea by pulling fluid from the gastrointestinal tract wall to dilute fluid. Examples of hyperosmolar fluids include fruit juice, soft drinks, and some commercial supplement beverages.
    - Conversely, hypo-osmolar fluids do not contain the glucose and sodium needed to optimize the absorption of fluids. Examples of hypo-osmolar fluids include water, sugar-free drinks, coffee, and tea.

- To optimize fluid and electrolyte absorption, use the recipe in Table 12-4 for a homemade oral rehydration solution (ORS) that provides an iso-osmolar beverage containing the ideal ratio of glucose and sodium.
  - Provide ORS at 1 L daily to start and up to 2 to 3 L daily.
  - ORS should be slowly sipped and consumed separately from foods.

Note: ORS can also be provided as flushes or continually via NG or OG tube.

Table 12-4. Oral Rehydration Solution (ORS) from Table Sugar and Salt

Ingredient	Measure
Sugar[a]	9 tsp
Salt[b]	tsp
Baking soda	tsp
Potassium chloride[c]	1/4 tsp
Water[d]	1 L

[a] Too much water can make diarrhea worse.
[b] Too much salt can be harmful to a child.
[c] If no potassium chloride is available, attempt to supplement with potassium-rich foods (eg, bananas, tomatoes, oranges).
[d] Be sure to use clean, safe drinking water.

Notes:
Wash hands with soap and water before preparing solution.
For the small and very sick, give ORS by teaspoon.
Give frequent, small sips.
Give enough ORS for the patients to pass pale, yellow urine, four or five times per day.
If the patient vomits, wait 10 minutes and begin again.
Feed after every loose bowel movement.
Continue to give solid foods as tolerated with ORS.
Make a fresh solution every 24 hours.
Table courtesy of Nutrition and Diet Therapy Branch, US Army Medical Center of Excellence.

Table 12-5. Food Examples for Blenderized Feeding

Nutrition type	Examples
Carbohydrates	Sweet potato, banana, oats, juice, rice, fruits without seeds, pumpkin, squash, mashed potato, cereal, applesauce
Fats	Avocado, butter, olive oil, milk, peanut butter
Proteins	Chicken, tuna, turkey, protein powder, Greek or regular yogurt, cooked chickpeas, fish, cooked eggs
Micronutrients	Cooked carrots, spinach, broccoli, blueberries, tomato juice, crushed multivitamins

- Vitamins and minerals.
  - Patients who are critically ill or injured can benefit from increased micronutrients such as a complete multivitamin.
  - The risk of toxicity from micronutrients provided in a complete multivitamin over 4 to 6 weeks is relatively low compared to the benefit.
  - Provide a *complete* multivitamin. Multivitamins such as gummies and chews lack many micronutrients and are not nutritionally complete.
  - A chewable multivitamin may be easier for a patient to consume and easier to crush and provide through an OG or NG tube.
  - Be cautious about providing a multivitamin with iron to patients receiving more than 10 or 20 units of blood, as these patients may be at risk for transfusion iron overload.[8]

How to Feed Patients

Oral Feeding

If possible, provide nutrition via oral ingestion.

Blenderized Feeding

If tube-feeding formula is unavailable or patients with facial trauma cannot chew or swallow, you may create a "homemade" formula using available food items (Table 12-5). Mix food items with milk,

broth, clear or full liquid supplements, or water to thin the mixture to an appropriate consistency (like a thin milkshake). Use a syringe or pump via OG or NG tube to administer feedings. When preparing the blenderized recipe, choose thoroughly cooked soft food items. Avoid heavily seasoned foods and foods containing bones or seeds, peels, or other fibrous material that may clog the feeding tube.

Enteral Feeding

If the patient cannot consume nutrients orally, use enteral feeding (EN) via feeding tubes. EN is a specialized nutrition support that provides calories, protein, electrolytes, vitamins, minerals, trace elements, and fluids via a tube through the nasal or oral cavity into the stomach or upper portion of the duodenum. Provide EN exclusively or in addition to oral intake of food and beverages or other forms of nutrition support such as parenteral (IV) nutrition therapies. See Table 12-3 for an algorithm on when to begin EN feeding based on hold time and patient condition.

Enteral Feeding Procedure. Follow these steps for EN feeding:

1. Keep the patient's head or head of the bed elevated at 30° to 45° to decrease aspiration risk.
2. Start at 20 mL/h and increase by 20 mL/h every 4 hours (as tolerated) to a predetermined goal rate.

Note: Once at the goal rate, if tube feeding is temporarily held for reasons other than intolerance, you can restart at the goal rate.

3. Flush the tube every 4 hours and before and after providing medication or anything by syringe. Use at least 30 mL of a thin liquid such as water, ORS, or normal saline (if indicated).

Note: Routine flushes maintain feeding tube patency and prevent clogs that require removal and replacement of the NG or OG tube.

4. Change bags and tubing every 24 hours. Consider changing all tubing and bags at midnight as a standard practice routine.
5. Write the time and date of bag changes on the actual bag.

Table 12-6. Bolus Tube Feeding Recommendations

	Constant tube feeding rate	Bolus 4 times per day[ab]	Bolus 6 times per day	Bolus 8 times per day
Male (30 cal/kg)	130 mL/h	650 mL per bolus over 30 min	425 mL over 20-30 min	325 mL over 15-20 min
Male (35 cal/kg)	150 mL/h	750 mL over 30-40 min	500 mL over 20-30 min	375 mL over 15-20 min
Female (30 cal/kg)	105 mL/h	525 mL over 20-30 min	350 mL over 15-20 min	250 mL over 15 min
Female (35 cal/kg)	120 mL/h	600 mL over 30-35 min	400 mL over 20 min	300 mL over 15 min

[a] Deliver 100 mL at a time over 5 minutes.
[b] Flush with a minimum of 30 mL water, oral rehydration solution, or saline solution before and after bolus.
Note: Do not mix medications in with the tube feeding due to the risk of creating a clog in the feeding tube. Deliver them separately, preferably before feeding.
Data sources: US Department of the Army. Nutrition Standards and Education. DA; 2017. DA Regulation 40-25.
McClave S, Taylor B, Martindale R, et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient. *J Parenter Enteral Nutr*. 2016;40:159-211. doi:10.1177/0148607115621863

Enteral Feeding Options. Some feeding options may not be feasible or practical in a PC environment. Consider the following EN options:

- ***Good***—Bolus feeding delivers nutrition intermittently through a syringe over a short time. Table 12-6 provides bolus feeding recommendations based on gender and required caloric intake rate.
  - Give 20 mL bolus feeds every hour or 500 mL bolus feeds every 4 hours, depending on patient tolerance.
  - Smaller, frequent bolus feeds are typically better tolerated than larger, less frequent boluses.
  - A general rule of thumb is to space the total bolus amount by 100 mL every 5 minutes.
  - It is a practical choice in a PC environment with limited equipment, but it requires sufficient staffing to accomplish several feedings in 24 hours.
- ***Better***—Cyclic feeding delivers nutrients longer with a pump or via gravity.
  - Gravity drip. Gravity-feeding bags provide a way to feed patients slowly over time.
    - Follow these six steps to perform gravity drip feeding:
      1. Hang bags filled with formula.
      2. Start with a closed roller clamp.
      3. Prime the gravity bag tubing by opening the clamp and holding the line over a cup until all the air is out.
      4. Flush the NG or OG tube.
      5. Connect the gravity bag tubing to NG or OG tube.
      6. For continuous infusion, set the drip rate following Table 12-7 based on closest hourly goal rate. Note that there is variance in formulas where a higher viscosity formula, like blenderized tube feeding, will drip slower and will lead to not meeting the patient's nutritional needs if using the algorithm below.
      7. Alternatively, you can pour a predetermined amount of enteral formula, milk, oral rehydration solution, etc into the gravity bag and use

Table 12-7. Gravity Drip Rate Feeding Chart in Increments of 25 mL/h

Drops per 15 s[a]	Drops per 1 min[a]	Hourly rate (mL/h)
2	6	25
4	12	50
5	18	75
7	24	100
8	30	125
10	35	150
11	41	175
13	47	200

[a] Rounded to the nearest drop.

the roller clamp to control the rate of feeding. Infuse over 30 minutes to prevent gastrointestinal upset due to rapid entry of formula into the stomach.

- This option should be available in most PC settings with limited equipment.

- Feeding pump. These convenient, powered pumps deliver nutrients at a fixed rate.
  - Cyclic feeding with pumps is an appropriate option in a resource-constrained environment. It allows sharing a pump with another patient.
  - Pumps provide feeding for 8 to 12 hours.
  - Multiply hourly goal rates by 24 for the total volume to be given in one day and divide by hours available for cyclic feeding.
  - If available in a PC setting, each pump can support more than one patient.

Note: Each pump can be used to cyclically feed up to three patients 8 hours per day or rotated to provide 30 minutes of bolus feeding six times per day for up to eight patients.

  - For a feeding pump or gravity drip bag:
    - The hang time should be 4 hours at most for blenderized tube feeding (see below).
    - If using a commercially prepared formula, the hang time is 8 to 12 hours to prevent microbial growth.
- ***Best***—Continuous infusion feeding delivers nutrients via a pump at a constant rate over 24 hours.
  - Ensures optimal nutrition.
  - If available in a PC setting, it requires the least staffing of all feeding methods.

Enteral Feeding Tips. Use the following tips to optimize EN feeding and improve safety:

- If the patient can safely eat and drink, you can allow them to consume food and beverages while the NG or OG is still in place. Fluids and texture-modified, softer foods are easier to chew and swallow.
- Hold all fluids and feeding *other than necessary to provide medications* 8 hours before anticipated surgery.
- NG and OG tubes can become clogged due to medications, not administering free water flushes, and coughing or emesis. Using warm water and massage, employ a push-pull method to help break up a clog. Do not use carbonated beverages (eg, sodas) to treat a clogged feeding tube.
  1. Use the syringe plunger to push water into the tubing and massage the tubing to loosen the clog.
  2. Pull back the plunger to dislodge the clog.
  3. Remove all fluid from the tube if you continue to meet resistance. Instill with warm water and clamp the tube for 20 to 30 minutes. Periodically perform the "push-pull" motion with the syringe and massage the tube to loosen the clog.

Special Patient Situations and Other Considerations

Documentation

Appropriate documentation of the nutrition care process communicates the patient's needs, promotes patient safety, and supports continuity of treatment as the patient moves to higher

echelons of care. Relevant nutrition-related information to share in the documentation process includes nutrition risk, nutrition interventions, food preferences, meal assistance, and oral care. A documentation template can facilitate accurate, relevant, and timely recording of this information. Annex A provides a basic template for nutrition documentation during PC. Proactively incorporate nutrition documentation forms into patient charts and trauma packets to alleviate time and resource constraints when providing care in the PC setting.

Medication Administration

- Medications[1]:
  - Crush the medication as finely as possible and mix it with water. Refer to the specific medication insert or consult a pharmacist to ensure the medication can be safely crushed.
  - Hold enteral nutrition and flush the NG or OG tube with 30 mL of water before and after the delivery of medication to prevent tube clogging.
  - Restart feeding immediately after medication administration.
  - Give each medication separately and flush with 10 mL of warm water between medications. Do not mix medications and give them at one time. Do not add medications to enteral formulas, as this can increase the risk of clogs and decrease medication delivery.
  - Consider timing and clustering care by bolusing (medications, supplements, etc) via the NG or OG tube for efficiency. For example, stop enteral feeding. Deliver a 30 mL water flush, deliver the first crushed medication, deliver a 10 mL water flush, deliver the second crushed medication, deliver a 10 mL water flush, deliver a protein supplement, flush with 30 mL water, and re-initiate enteral feeding.

Burn Patients

Nutrition. Patients with burn injuries and extensive wounds have special nutritional needs because they become hypermetabolic, with a total energy expenditure of up to two or three times the basal metabolic rate. Without adequate nutrition, these patients can experience the adverse effects of catabolism,

such as impaired immunity, decreased wound healing, and pneumonia. Use the following guidance to help manage burn patients:

- Provide early and daily optimal nutrition. It is imperative to modulate the hypermetabolic and hyper-inflammatory state, promote wound healing, and maximize participation in rehabilitation.
  - Place an NG or OG tube in patients with greater than 20% TBSA burn or less than 10% TBSA burn with other associated trauma unless patients can meet calorie and protein goals through oral intake.
  - If the patient cannot eat or drink, start feeding once the patient is hemodynamically stable.
  - Guidelines state it is safe and recommend initiating feeding within 4 to 6 hours of a large burn.[1]
  - Add a complete multivitamin daily until the patient's open wound size is less than 10% TBSA to support the increased need for vitamins and minerals due to wound losses and wound healing.

Hydration. Burn patients often become hypervolemic and hyponatremic. Additionally, burn patients experience a profound thirst response (they may even drink toilet water to quench their thirst). This intense and prolonged thirst response returns to normal once wounds heal. Until then, they may drink volumes of water that can cause severe hyponatremia. Beverages other than milk and supplements are not recommended for these patients because they have higher amounts of free water that can contribute to hyponatremia and are not calorically dense enough to meet the nutritional needs of wound and burn patients.

- Unless otherwise prescribed through an ORS protocol for fluid resuscitation, do not give fluids (including water) other than milk and supplements until the patient:
  - has less than 10% TBSA open wounds,
  - is meeting their calorie goal, and
  - is not experiencing hyponatremia.
- Do not give caffeine to burn patients, as it can increase the metabolic rate by 3% to 11% in already hypermetabolic patients.

Refeeding Syndrome

Refeeding syndrome was first described after World War II when concentration camp survivors, war prisoners, and famine victims experienced increased morbidity and mortality after the re-introduction of food and beverages. Fluid and electrolyte shifts of phosphorus, potassium, and magnesium characterize refeeding syndrome. These shifts result from nutrition repletion and subsequent insulin secretion after a prolonged period of starvation or from increased catabolism and physiological demands that deplete micronutrient reserves within the body.

Although there is not a set of standardized diagnostic criteria, biochemical abnormalities of hypophosphatemia, hypokalemia, hypomagnesemia, hypocalcemia, hyperglycemia, and thiamin deficiency can occur as part of this syndrome, which can result in cardiopulmonary compromise and arrest.[9] Potential risk factors include[9]:

- Recent significant weight loss (>5% of body weight), whether intended or unintended.
- No (or negligible) nutrition intake for 5 to 6 days.
- Less than 75% of estimated nutritional requirement for more than a month.
- Loss of subcutaneous fat.
- Loss of muscle mass.
- Chronic alcohol or drug use.
- Major illness, surgery, or burn that increases metabolism.

Management recommendations for refeeding syndrome include the following[9]:

- If able to monitor electrolytes, monitor every 6 hours.
- If unable to monitor electrolytes, provide multivitamins and 25% of regular rations for 2 to 3 days and increase rations by 25% every 2 to 3 days, as able, until electrolyte monitoring and repletion are complete.
    - Provide formula at 20 mL/h or reduced volume at 50% of the goal feeding rate for enteral nutrition.

- Use clinical judgment to balance the risks and benefits of nutrition provision with the pace of progression. If a patient has multiple risk factors, reduce provisions and slow advancement. It is better to reduce feeding and intake when there is a concern for refeeding syndrome and electrolyte abnormalities than to risk feeding. Feeding can cause electrolyte derangements, resulting in the inability to breathe and cardiac dysfunction.

Aspiration

In aspiration, oral secretions, foods, and beverages enter the lungs instead of the esophagus and stomach. Dysfunctional swallowing and regurgitation or reflux of stomach contents can lead to aspiration, and aspiration can result in pneumonia. Follow the EN guidelines in this chapter to mitigate the risk of aspiration in tube-fed patients. For patients with oral intake, the following are risk factors for aspiration[1]:

- Inability to protect the airway (due to neurological function or reduced consciousness).
- Supine positioning.
- Vomiting.
- Poor oral care.

Conduct a swallow risk screening assessment algorithm to help assess aspiration risk (Annex B). Note that "silent aspiration" can be undetected by a swallow risk screening evaluation and still occur, so consider aspiration risk as part of ongoing assessments in at-risk patients.[10]

Assess enteral nutrition tolerance at least every 12 hours. Signs of intolerance include the following:

- Vomiting.
- Diarrhea.
- Reduced passage of flatus or stool.
- Abdominal distention.
- Tightening of the abdomen.
- Complaints of abdominal pain or discomfort.

If the patient shows intolerance, reduce enteral feeding to 20 mL/h or withhold feeding for 4 hours and then reassess. If signs

of intolerance resolve, restart feeding and reassess again in 4 hours. If signs of intolerance do not resolve, reassess every 4 hours. If possible, continue feeding at 20 mL/h.

Note: The gastric residual volume (GRV) is not an accurate predictor of intolerance to enteral nutrition.

Lessons Learned and Recommendations

Although there are many potential challenges associated with providing patient care during PC, several case studies are available for information. For example, the global response to COVID-19 offers key insights into prolonged patient care in suboptimal conditions. Overwhelmed by the number of patients, under-resourced hospitals responding to COVID-19 experienced many of the same challenges anticipated to arise during the response to large-scale combat.

In a recently published case report, a nutrition care team responding to COVID-19 in New York City described challenges with staffing, medical supply, and electronic charting. To overcome barriers in this unique environment, the nutrition care team identified the need for easy-to-use screening tools, alternatives to electronic charting, and creative resources to mitigate shortages.[11] Similarly, Army registered dietitians deployed to Afghanistan during the COVID-19 pandemic also noted a lack of nutrition expert availability at forward treatment locations and a shortage of available supplies. Considering these findings, outlined below are suggested recommendations for future deployed nutrition care operations:

- Addition of nutrition screening and documentation tools in the Joint Trauma System Clinical Practice Guidelines for Nutrition.
- Addition of nutrition "smart cards" to Joint Trauma System Trauma Care Resources. These smart cards may include quick reference sheets calculated by a dietitian. Examples of smart cards may include set tube-feeding rate calculations, estimated macronutrient requirements, fluid recommendations, and supplement calculations.
- Expand supply sets for Roles 1 and 2 to include supplies to support patient feeding. Suggested items to build a nutrition treatment set include:

  - Enteral formulas and protein powders.
  - Liquid supplements and ultra-high-temperature milk.
  - Carbohydrate electrolyte beverages and oral rehydration solutions.
  - Syringes, whisks, and blenders.
  - Feeding pumps and gravity feed bags.
  - Fiber and complete chewable multivitamins.
- Addition of nutrition care scenarios to combat medic and corpsman training. Possible training topics include:
  - Screening a patient for nutrition risk and malnutrition.
  - Diet types and feeding modalities.
  - Supplements and their best utilization.
  - Setting up and operating a feeding pump.
  - Texture-modified diets and thickened beverages.
  - Assessment of weight, muscle, and fat loss associated with malnutrition.
- Nutrition training short courses or clinic rotations for combat medics, nutrition care specialists, corpsmen, cooks, and other ancillary providers may serve as a great forum to cross-train personnel and alleviate the burden of care. Possible training topics may include:
  - Blenderized "homemade" tube feeding.
  - Preparation of therapeutic diets/meals.
  - Diet types and feeding modalities.
  - Setting up and operating a feeding pump.
- Integrate Holistic Health and Fitness (H2F), Operation Support Team, and other embedded registered dietitians and nutrition care specialists. Utilize respective service-embedded nutrition assets with operational units to assist Role 1, Role 2, and other forward medical teams with patient feeding operations. Exercise these resources before deployment with patient feeding scenarios at Role 1 and Role 2 levels of care during combat training center rotations and other culminating training events.

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Annex A

Suggested Nutrition Documentation Form

Name:	DOB:	Admit date:
Age: Ht:	Weight:	Usual weight:
Reason for admission/Dx:		
Labs:		
Meds:		
GI: N / V / D ?	Yes / No Last BM?	If yes, # days?
Food allergies/intolerances?	Yes / No	If yes, specify:
Special diet (including cultural/religious needs)?	Yes / No	If yes, specify:
Estimated calorie needs:		

Annex A (continued)

Suggested Nutrition Documentation Form

Nutrition intervention/diet order:

Oral diet: type?

Tube feed: type/rate?

Supplements: type/frequency?

Other:

Followup interventions:

Comments/concerns:

Annex B

Swallow Risk Screening Note

Pre-Swallow Checklist (Part 1)	**YES**	**NO**
1. Patient is awake and alert or responding to speech. If NO stop and rescreen in 12-24 hours		
2. Patient can be positioned upright, with some head control. If NO stop and rescreen in 12-24 hours		
3. Patient can cough when asked. If NO stop and rescreen in 12-24 hours		
4. Patient can maintain some control of their saliva. If NO stop and rescreen in 12-24 hours		
5. Patient can lick their top and bottom lips. If NO stop and rescreen in 12-24 hours		
6. Patient can breathe freely (ie, no difficulty breathing or problems maintaining SaO_2). If NO stop and rescreen in 12-24 hours		
7. The patient can speak without a WET or HOARSE-sounding voice. If NO stop and rescreen in 12-24 hours		
8. The patient is absent of oral or facial weakness. If NO stop and rescreen in 12-24 hours		
9. The patient can manage their own secretions (no drooling). If NO stop and rescreen in 12-24 hours		

Reassess every **12 to 24 hours**, and if the patient remains inappropriate for oral intake, refer to the algorithm for when to consider enteral feeding.

Annex B (continued)

Swallow Risk Screening Note

Pre-Swallow Checklist (Part 2) • Position the patient as close to 90 degrees as possible. • Perform the 3-ounce water challenge: give the patient a cup containing 3 ounces of water and ask them to drink it without interruption.	**PASS**	**FAIL**
1. The patient can drink the entire amount. NO = FAIL		
2. The patient coughs or chokes up to 1 minute after completion. YES = FAIL		
3. The patient has post-swallow wet-hoarse vocal quality. YES = FAIL		
• If the patient **PASSES**, allow intake of fluids and foods while closely observing patient for any above signs of symptoms of aspiration. • If the patient **FAILS**, stop. Rescreen in 12 to 24 hours or refer to the enteral feeding algorithm. **Note:** Document screening results regardless of Pass or Fail status.		

Time/date: _____

Screen performed by (rank, name, MOS/AOC):

_____

Adapted from the Brooke Army Medical Center Swallow Risk Screening Note

Chapter 13

PATIENT MOVEMENT

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Introduction

Patient movement (PM) is the transport of sick, injured, and wounded persons to obtain medical or dental treatment. The US Armed Forces and North Atlantic Treaty Organization (NATO) use PM to link a tiered casualty care system, creating a seamless continuum from the point of injury or illness (POI) to definitive medical treatment. Provision of uninterrupted care during rapid evacuation enhances a patient's prognosis and reduces morbidity and mortality.[1–3]

When PM is delayed, prolonged care (PC) ensures ongoing management of injuries or illness while awaiting evacuation. PC ends when the patient is evacuated. Understanding the complexities of PM is essential for all forward medical teams, including those providing PC, to arrange evacuation and prepare patients for a transition of care.

Echelons of Care

Health Service Support (HSS) provides casualty care via a phased healthcare system, which starts at the battlefield, moves rearward through the operational area (OA), and ends in the continental US (CONUS). Patient care begins at POI and progresses stepwise with increasing clinical capabilities at each higher level. There are five echelons of care at the core of HSS (Figure 13-1).

Note: PC typically occurs at Role 1 or 2 when PM to higher levels of care is delayed.

Role	Army	Navy	Marine Corps	Air Force
1 First responder	Tactical combat casualty care (TCCC) Nonmedical: All service members (TCCC-ASM), combat lifesavers (TCCC-CLS) medical personnel (TCCC-MP): combat medics, corpsman, medical technicians			
2 Forward resuscitative care	Battalion aid station	Ship/submarine medical department	Battalion/wing aid station	
	[a]Forward surgical team / forward resuscitative and surgical detachment	Fleet surgical team	[b]Shock trauma platoon	Forward resuscitative surgery system	Ground surgical team Special operations surgical team
	Medical company (area support) (brigade support)	Aircraft carrier Casualty receiving and treatment ship	Medical battalion surgical company	Expeditionary medical support
3 Theater hospitalization	Combat support hospital Field hospital	Hospital ship	Expeditionary medical facility	Theater hospital
4 Definitive care	Veterans' hospitals ↔ United States and overseas medical treatment facilities ↔ Civilian hospitals			

Figure 13-1. US Armed Forces roles of medical care and associated care capabilities as compared across service components.

[a] Army Forward Surgical Team/Forward Surgical Resuscitative Team is a Role 3 capability used to expand care available at Role 2 by providing resuscitative surgical care.

[b] Marine Corps Shock Trauma Platoon is a Role 2 capability that can be used to expand care available at Role 1 by providing advanced resuscitative care.

Adapted from Figure II-1. Notional United States Military Roles of Medical Care. In: *Joint Health Services*. Office of the Chairman of the Joint Chiefs of Staff. 11 December 2017. JP 4-02.

The 10-1-2 (+2) rule, as follows, defines a timeline for critical intervention at each stage of resuscitative care:

- Within 10 minutes from POI—any available service member initiates immediate lifesaving measures.
- Within 1 hour from POI—medical personnel begin prehospital emergency care.
- Within 2 hours from POI—medical teams perform surgical and resuscitative emergency care to preserve life, limb, and function.
- No more than 2 hours after damage control surgery, tactical evacuation (TACEVAC) to a higher level is initiated to allow for further surgical, resuscitative, diagnostic, and specialist care necessary to stabilize the patient for strategic evacuation (STRATEVAC).

Note: Operational factors can prevent the movement of casualties to surgical emergency care or delay evacuation to higher levels of care after damage control surgery, resulting in teams with limited resources and holding capacity providing PC.

Role 1: First Responder Care

The continuum of care begins with nonmedical and medical first responders with limited resources and no real holding capability. Goals include:

- Initial treatment and stabilization.
- Movement of casualties without impeding the mission.

Tactical combat casualty care (TCCC) integrates tactics and medicine to accomplish these goals and includes the following medical objectives:

- Immediate lifesaving measures:
  - Stop massive hemorrhage.
  - Secure an airway.
  - Limited resuscitation with blood products.
- Treat disease and non-battle injuries to prevent degradation of function.

Phases of TCCC are as follows:

- *Care under fire* occurs in the presence of an immediate threat. Personnel continue to engage the enemy and minimize mission impact, with directed care only for massive hemorrhage.
- *Tactical field care* occurs in the absence of direct fire. Casualties are transferred to medical personnel, if available. Care focuses on life-threatening conditions, initial resuscitation, and patient comfort.
- *TACEVAC* includes expeditious PM by any available ground, air, or maritime assets. Additional personnel and equipment may be required to maintain a patient's condition during transport.

Role 1 begins at POI; most casualties enter the PM system here. Typically, there are minimal to no medical assets, and the member himself (or a battle buddy) initiates care if no medical personnel are available. Casualties may present to formal Role 1 facilities (battalion aid stations, shock trauma platoons, or ship medical departments) where medical personnel provide emergency care.

Role 2: Forward Resuscitative Care

Medical personnel with surgical capabilities, but limited resources and holding capacity, administer forward resuscitative care. The primary focus is emergency medical treatment for illness and advanced trauma management for battle injuries to preserve life and limb. Patients are held temporarily until transported to a higher level of care.

Compared to Role 1, capabilities at Role 2 are expanded with the following resources:

- Greater availability of blood products.
- Limited point-of-care laboratory.
- Radiography and ultrasound.

Additional services may include dental, combat and operational stress control, and veterinary medicine.

Capabilities and resources vary depending on the type of Role 2: light maneuver (R2LM) or enhanced (R2E). R2LM provides

advanced resuscitation and damage control surgery but has minimal capacity and no inpatient services, requiring evacuation of casualties to Role 3 before Role 4. R2E provides primary surgery, postoperative care with intensive care units and ward beds, and ancillary testing and services necessary to stabilize and evacuate to Role 4. Holding capabilities vary, but an R2E may be able to hold two to four critically ill patients for 24 to 48 hours.

Role 3: Theater Hospitalization

Field hospitals and hospital ships medically sustain forces within the OA. Theater hospitalization provides the essential care necessary to return patients to duty or stabilize patients for PM to definitive care outside of the OA. Role 3 hospitals have significantly expanded personnel, medical resources, and holding capacity. Capabilities cover primary inpatient and outpatient care, enhanced medical services including critical care medicine, surgical care including postoperative treatment, and ancillary services.

Although exact capabilities vary, a robust Role 3 may provide the following services:

- Expanded pharmacy.
- Expanded radiology, including computerized tomography scans.
- Clinical laboratory.
- Blood bank.
- Optometry.
- Dental.
- Behavioral health.
- Physical and occupational therapy.
- Veterinary medicine.

Additional medical and surgical specialties may include:

- Pediatrics.
- Obstetrics and gynecology.
- Cardiology.
- Infectious disease.
- Advanced burn management.
- Ophthalmology.
- Neurosurgery.

Role 4: Definitive Care

Definitive care is the destination in PM. Conclusive treatment for injury or illness is provided at US-based facilities, including military, civilian, and Veterans Affairs hospitals and robust overseas military treatment facilities (MTFs). Capabilities include comprehensive resources for preventive, curative, restorative, rehabilitative, and convalescent care not available at lower roles. Definitive care leads to recovery and rehabilitation with an eventual return to military duty or medical discharge.

En Route Care

En route care is the continuation of care during PM without compromising the patient's clinical condition. Medical personnel with the appropriate training and resources maintain the patient's current level of care and continue the treatment initiated before evacuation. Compared to casualty retrieval without advanced medical capabilities, en route care reduces morbidity and mortality.[3,4]

Transport times may range from minutes to hours, with some missions exceeding 24 hours, depending on patient needs and operational considerations. This critical mission requires integrating multiple evacuation systems with various transport platforms, from vehicles of opportunity to designated aircraft, paired with highly trained medical teams. This integration enables simultaneous treatment and movement of patients, both emergently and routinely, across the PM continuum.

Evacuation

The Patient Movement Mission

The PM mission employs a combination of dedicated, designated, and opportune ground, air, and maritime platforms within an OA and globally as an integral component of HSS. Operationally, PM is divided into TACEVAC, which encompasses all intratheater movements, and STRATEVAC, involving intertheater movements. PM is executed using medical evacuation (MEDEVAC), casualty evacuation (CASEVAC), and aeromedical evacuation (AE) (Figure 13-2). The types of

evacuation differ in terms of personnel and equipment, level of care, and mode of transport. PM of casualties after PC can use any of these evacuation systems.

PM is governed by doctrine at multiple levels, including the component services, the Department of Defense, and NATO. With numerous organizations involved, having a shared understanding of patient requirements and medical capabilities

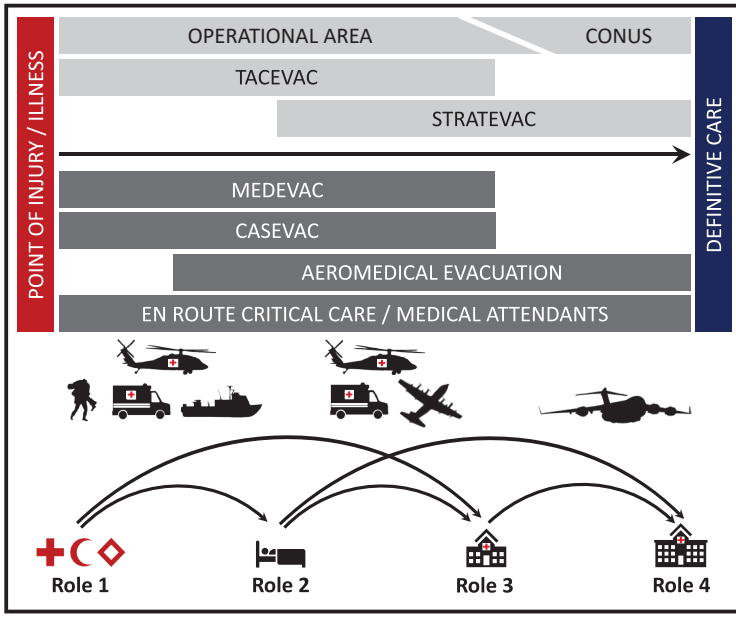


Figure 13-2. Patients are moved along the care continuum from point of injury to definitive care by a coordinated system. Tactical evacuation (TACEVAC) is patient movement within the operational area and is primarily performed by medical evacuation (MEDEVAC) but can also occur via casualty evacuation (CASEVAC) and aeromedical evacuation (AE). Strategic evacuation (STRATEVAC) is patient movement from the operational area to definitive care in the continental United States (CONUS) or robust overseas medical treatment facilities. En route critical care teams and medical attendants can augment patient movement when required to provide en route care.

throughout the PM system is crucial. Despite standardization efforts, differences in definitions and terminology exist. For this chapter, Joint Publication 4-02, *Joint Health Services,* is the primary reference when a discrepancy is present.

Factors Affecting Patient Movement

Operational and patient factors affect PM and determine where and how a casualty enters and moves through the PM system. Patient factors include:

- Injury type and severity.
- Clinical stability.
- Required medical specialties (eg, burn care or neurosurgery).

Operational factors include:

- Tactical situation.
- Communications capabilities.
- Availability of a means of evacuation.
- Proximity to transportation hubs, including airfields and seaports.
- Geographical location of medical assets and resources.
- Bed availability at MTFs.

Note: Operational factors can delay PM, requiring forward medical teams to provide PC.

Tactical vs. Strategic Evacuation

Available tactical modes of transport, including ground-based vehicles, rotary wings, limited fixed wings (eg, C-130), ships, boats, and other watercraft, execute TACEVAC. Patients are transported from POI to MTF or between MTFs within the same theater. Intratheater operations use theater resources directed by the combatant commander (CCDR). Dedicated MEDEVAC assets and designated CASEVAC and AE assets are all essential to intratheater PM. However, the primary method of TACEVAC during land-based operations is US Army MEDEVAC air and ground ambulances.

STRATEVAC is directed by US Transportation Command (USTRANSCOM), which oversees strategic airlift from the OA

to CONUS or allied nation facilities. This type of PM uses global mobility assets to transport patients over long distances and is primarily conducted by AE on fixed-wing platforms.

Both TACEVAC and STRATEVAC can use nonstandard modes of transport during situations such as a denied aerial environment in a near-peer conflict, a mass casualty, or a humanitarian disaster with damage to transportation infrastructure. TACEVAC may increase the use of maritime and ground assets, including non-traditional platforms such as trains and civilian vehicles of opportunity such as buses. STRATEVAC may employ military AE crews on civilian aircraft, and maritime assets may be used when US Air Force assets are unavailable.

Medical Evacuation

Mission Scope. The core principle of MEDEVAC is the provision of en route care with medical personnel trained and equipped to maintain patients during PM without deterioration in clinical status. The US Army defines MEDEVAC as providing en route care on *dedicated* transport platforms designed, manned, and postured exclusively for medical evacuation. The US Army and US Marine Corps operate ground ambulances. The US Army operates rotary wing ambulances supporting land-based operations and ship-to-shore PM. However, there are limited sea-based assets dedicated to the PM mission.

The primary mission of MEDEVAC is the timely and effective movement of wounded, injured, and ill persons from POI to MTFs and between MTFs within the theater. To this end, MEDEVAC supports the OA in the following roles:

- Locate, acquire, treat, and stabilize wounded, injured, and ill personnel.
- Evacuate casualties from POI while providing en route care.
- Clear the battlefield to decrease operational impacts and improve freedom of movement.
- Provide intratheater transfer between MTFs (eg, R2LM to Role 3).
- Provide emergency movement of medical personnel, equipment, and supplies such as blood products (secondary mission).

Casualty Collection Points and the Ambulance Shuttle System. MEDEVAC uses casualty collection points (CCP) and ambulance exchange points to ensure seamless transitions in the continuum of care (Figure 13-3). The CCP is a location where casualties are assembled for evacuation to an MTF by ground or air assets. They are predesignated along a line of advance or an evacuation route and may include medical personnel (eg, battalion aid station) or may only be a geographic location for pickup (without prepositioned medical personnel).

Ambulance exchange points are locations where patients are transferred from one ambulance to another en route to an MTF. The exchange points are typically preplanned, creating an ambulance shuttle system. This shuttle system has a relay point acting as a hub serving one or more loading points where patients are received.

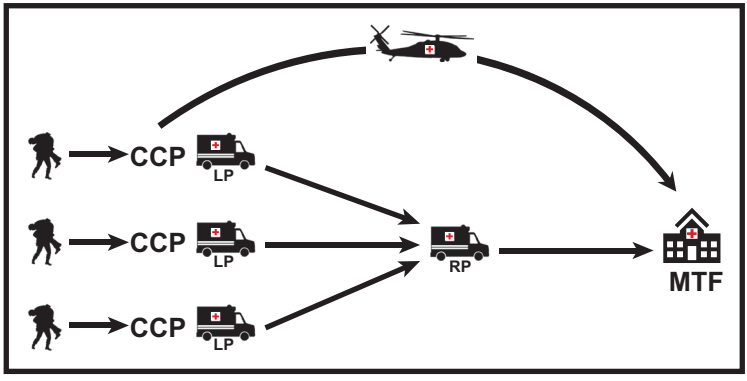


Figure 13-3. Casualty collection points (CCPs) are locations where casualties are assembled for evacuation by ground or air ambulances to military treatment facilities (MTFs). For ground transport, patients are transferred at ambulance exchange points, creating a shuttle system. An ambulance relay point (RP) acts as hub serving multiple ambulance loading points (LPs) where casualties are received from point of injury or Role 1 facilities.

Casualty Evacuation

CASEVAC is PM using nonmedical vehicles or aircraft without guaranteeing en route care. These vehicles and aircraft are not marked for medical transport or protected under the Geneva Conventions. CCDRs may designate transport assets for CASEVAC, in addition to their primary mission, or use vehicles or lifts of opportunity. CASEVAC is used when MEDEVAC assets are unavailable; however, diverting operational assets for CASEVAC can reduce combat effectiveness, and this impact must be weighed against evacuation requirements. Medical personnel and equipment may be paired with opportune transport platforms, or patients may be moved without medical personnel. At a minimum, combat medics or corpsmen and combat lifesavers are recommended to augment CASEVAC when possible.

CASEVAC-capable assets can complement MEDEVAC assets and increase options for PM from the combat area. Casualties with severe or life-threatening injuries are prioritized for MEDEVAC, and CASEVAC can transport those with less severe injuries or illnesses if the MEDEVAC system is overwhelmed. CCPs can be used to triage casualties to different types of evacuation (MEDEVAC vs CASEVAC).

Aeromedical Evacuation

Mission Scope. AE provides en route care and is the primary entity for STRATEVAC, but it also has an increasing role in TACEVAC, providing longer intratheater PM on fixed-wing aircraft as the deployed medical footprint decreases. AE uses dedicated teams of medical personnel combined with designated multi-role aircraft to execute the PM mission. Most AE PM uses US Air Force mobility aircraft but may also use sister service, civilian contracted, and international partner airframes.

The scope of AE includes regulated and unregulated, inter- and intratheater PM. AE can include TACEVAC from POI in forward operating areas at the CCDR's discretion; however, PM from POI to Role 2 is typically the responsibility of the service component, and AE traditionally receives patients from a secured airfield.

The Aeromedical Evacuation System. The US Air Force is responsible for all aspects of AE and, in addition to training and deploying medical evacuation teams, provides command and administrative support and ground support for PM. AE is an integrated system that results in a single entity providing all aspects of regulated PM regardless of the service component.

The Aeromedical Evacuation Crew (AEC) and the En Route Patient Staging System (ERPSS) are two basic components of AE. The AEC provides the foundation of AE medical care and includes flight nurses and aeromedical evacuation technicians. The ERPSS is an essential ground component of AE that facilitates en route care and provides patient holding, staging, and processing upon entry and exit from the AE system. ERPSS stages in proximity to secure airstrips, prepares patients for transport, and provides ground transport between the airstrip and MTF.

En Route Critical Care

When patient requirements are beyond the capabilities of an AEC, a medical attendant or an En Route Critical Care (ERCC) team with specialty training can be used. ERCC teams deploy with mission-specific equipment and expand the scope of AE's medical care and PM capabilities or, less frequently, MEDEVAC and CASEVAC. These teams provide intensive care for critically ill or injured patients who require extensive resuscitation, life support systems, hemodynamic monitoring, and lifesaving procedures. As such, ERCC has transformed the PM capabilities of the AE mission. The most common and only permanent ERCC capability is the Critical Care Air Transport Team (CCATT). However, ERCC includes additional mission-specific Special Medical Attendant teams: US Army Institute of Surgical Research (USAISR) Burn, Extracorporeal Membrane Oxygenation (ECMO), and Neonatal Intensive Care Unit (NICU). Except for NICU, Special Medical Attendant teams are tasked with CCATT because they do not represent stand-alone capabilities.

CCATT is the main ERCC asset and includes a physician, nurse, and respiratory therapist who provide critical care medicine to a wide range of patients during PM. Teams carry advanced medical equipment that can care for six patients requiring advanced care

but not mechanical ventilation, or up to three patients requiring mechanical ventilation. Medical attendants can augment CCATT for specific patient populations, for instance, a pediatrician for a critically ill child, an obstetrician for a high-risk pregnancy, or a dialysis nurse for a patient requiring renal replacement therapy. Typical transport platforms include C-17 and KC-135 for STRATEVAC and C-130 for TACEVAC, but CCATT are trained to use any aircraft of opportunity, including rotary and fixed-wing assets.

The CCATT mission and capabilities continuously evolve to meet changing operational requirements. Although typically embedded with and augmenting AE for STRATEVAC, CCATT may be independently tasked by the CCDR to augment any PM, including MEDEVAC, CASEVAC, and special operations teams. Independent tasking is an essential function of CCATT as the deployed footprint decreases and geographically dispersed forward surgical teams operate in austere conditions, requiring longer TACEVAC or even STRATEVAC from Role 2. CCATT acts as a force multiplier to support this far-forward medical capability throughout an OA by ensuring en route care of unstable and incompletely resuscitated patients during PM.[4,5]

Contaminated and Contagious Patients

In a chemical, biological, radiological, and nuclear (CBRN) environment, patients are first treated and decontaminated in place. Per USTRANSCOM policy, personnel with known or suspected CBRN exposure will not be transported on AE assets before decontamination. If PM is essential to preserve life or continue critical missions, the patient is decontaminated to the extent possible before PM, and efforts to prevent contamination spread are implemented. If crossing international boundaries, these rare cases must be authorized for PM at multiple command levels (eg, CCDR, USTRANSCOM/CC, Secretary of Defense) and by diplomatic authorities.[6,7]

Infection control and precautions for contagious diseases, including those transmitted by droplets (eg, influenza) and airborne (eg, tuberculosis), are paramount during PM. Patients

may be isolated or asked to wear a mask when appropriate and are positioned in relation to airflow within the aircraft to decrease the risk of disease spreading to other patients.

Biocontainment is required for personnel affected by weaponized biologics and outbreaks of high-consequence infectious disease (HCID). Examples of HCID include coronaviruses (eg, severe acute respiratory syndrome and COVID-19 disease) and viral hemorrhagic fevers (eg, Ebola and Marburg virus disease). These patients are primarily treated in place. However, transportable biocontainment units such as the Negative Pressure Conex are used if PM is required to preserve life or due to operational requirements. Additional authorization beyond standard validation is necessary for PM of HCID.[7,8]

Note: Patients with CBRN or HCID exposure may require PC as they are primarily treated in place, and if PM is needed, significant delays are expected due to requirements for specialized equipment and additional authorization for PM beyond standard validation.

Medical Regulating

Medical regulating ensures effective PM by matching patients with MTFs with the necessary medical capabilities and available bed space. Medical regulating is vital to executing PM after PC because teams must understand the appropriate regulating authorities with whom to coordinate and request evacuation.

Administrative Oversight

The PM system operates worldwide and includes oversight and coordination of bed-lift planning, patient selection, route planning, and movement control. Medical regulating entities include local component commands, the Patient Evacuation Coordination Cell (PECC), and the Patient Movement Requirements Center (PMRC).

Component commands are responsible for PM from POI to Role 2. The US Army MEDEVAC Operations Cell oversees ground and air ambulances. The US Navy uses lifts of opportunity. The

US Marine Corps relies on dedicated ground evacuation assets, designated air assets, and lifts of opportunity. If US Air Force assets are required at this evacuation level, lifts of opportunity may be used. In the joint environment, the PECC coordinates PM within theater between service MTFs, host national facilities, and organic theater assets.

Component commands or the PECC oversee TACEVAC from Role 2 to Role 3. Alternatively, if a Patient Movement Request (PMR) is submitted, the appropriate PMRC coordinates PM from that point onward. The service component and/or PECC coordinates transition points for the handoff of PM to the appropriate PMRC, ensuring continuity of en route care. Global PMRC (GPMRC) oversees strategic evacuation (STRATEVAC) out of the theater to Role 4.

Patient Movement Requirements Center. PMRC integrates medical regulation responsibilities, transportation requirements (eg, the best mode of available transportation), and mission requirements (eg, medical crew and equipment) to move the patient safely and efficiently. The Theater PMRC (TPMRC) regulates intratheater movements. TPMRCs are responsible for intratheater PM and maintaining visibility of bed availability and medical capabilities at MTFs. Intertheater PM is conducted by USTRANSCOM and is overseen by the GPMRC. In contingency operations, a Joint PMRC (JPRMC) can deploy to support specific theater requirements. The JPMRC coordinates with the appropriate TPMRC and the GPMRC for intra- and intertheater movements, respectively.

Theater Evacuation Policy. The theater evacuation policy determines which patients to evacuate. This policy is a command decision that determines the maximum period of non-effectiveness that patients may be held within the theater for treatment. When a patient cannot return to duty status within the defined period, they are evacuated by the first available means, as long as travel will not aggravate their disability or medical condition. In a combat zone, this typically means that an injured or ill service member who cannot return to duty within 7 days is evacuated.

Evacuation Request

Precedence. Evacuation precedence determines how rapidly PM occurs. The originating facility initially assigns precedence, which can be upgraded or downgraded as a patient moves through the care continuum. Per international law, casualties are categorized solely by medical condition and without distinction based on sex, race, nationality, religion, political opinions, or other similar criteria. Priorities of movement are as follows:

- Priority I (Urgent) requires immediate PM to save life, limb, or eyesight and prevent permanent disability or serious complications of injury or illness.
- Priority IA (Urgent Surgical) requires immediate PM to forward surgical intervention before further evacuation.
- Priority II (Priority) requires expedited PM for prompt medical intervention that is unavailable locally or if the medical condition could deteriorate.
- Priority III (Routine) requires PM, but the patient's condition is not expected to deteriorate.
- Priority IV (Convenience) requires evacuation but does not require PM on a medical vehicle.

Table 13-1 details time frames for TACEVAC and STRATEVAC based on evacuation precedence.

Table 13-1. Evacuation Timeline by Precedence[a]

Evacuation precedence		TACEVAC	STRATEVAC
Priority I	Urgent	1 h	12 h
Priority IA	Urgent Surgical	1 h	N/A
Priority II	Priority	4 h	24 h
Priority III	Routine	24 h	72 h
Priority IV	Convenience	If available	N/A

[a] Patients should be evacuated within the time frames specified for tactical evacuation (TACEVAC) and strategic evacuation (STRATEVAC) according to assigned precedence. Priority IA and IV are not used for STRATEVAC. Priority IV is used when transport on a medical vehicle is a matter of convenience, not necessity.

9-Line MEDEVAC Request. Evacuation requests at the tactical level are submitted via a 9-line MEDEVAC request (Figure 13-4), a standardized format used to expedite evacuation. This request should be made using secure communications. A Mechanism, Injuries, Signs/Symptoms, Treatment (MIST) report (Figure 13-5) should be sent after the 9-line if available.

Note: If a MIST report is not sent with the 9-line MEDEVAC request, it should be given as a written or verbal report at patient handoff.

Patient Movement Request. The MTF requests further PM by submitting a PMR via TRANSCOM Regulating and Command & Control Evacuation System (TRAC2ES). The PMR is routed to the appropriate PMRC based on the location of the patient and the movement requested. PMRC evaluates the request for necessity, acuity, eligibility, precedence, and mode of transport. A theater validating flight surgeon provides medical direction and oversight of PM validation to ensure en route care. The PMR is sent to the appropriate command and control agency to allocate airlift upon validation. In certain operational situations, including immediate danger or mass casualty events, unregulated casualties may be moved by USTRANSCOM assets without prior validation by PMRC. These patients are cleared for evacuation by a validating flight surgeon (if available) or another medical authority without prior validation by PMRC.

TRANSCOM Regulating and Command & Control Evacuation System. TRAC2ES is a centralized, regulated system used at both global and theater levels to monitor, forecast, and plan operations. It provides a virtual environment for creating and managing PMRs, tracking patient location, updating MTF capabilities and bed capacity, and producing a MEDEVAC mission report and Air Force Form 3899 (Aeromedical Evacuation Patient Record). TRAC2ES maximizes the effectiveness of PM by matching patient requirements with appropriate MTFs and available transport solutions.

Documentation

Although challenging in military medicine's fast-paced and dynamic environment, documentation is critical to safe, ethical,

9-LINE EVACUATION REQUEST

Line 1 Location

Line 2 Radio Frequency & Call Sign

Line 3 Number of Patients by Precedence
_____ A - Urgent
_____ B - Urgent surgical
_____ C - Priority
_____ D - Routine
_____ E - Convenience

Line 4 Special Equipment
A - None
B - Hoist
C - Extraction
D - Ventilator

Line 5 Number of Patients by Type
_____ L - Litter
_____ A - Ambulatory

Line 6 Security of Pickup
N - No enemy troops in area
P - Possible enemy troops
E - Enemy troops (approach with caution)
X - Enemy troops (armed escort required)
* *Peacetime*: NUMBER AND TYPE OF WOUNDED

Line 7 Method of Marking Pickup Location
A - Panel
B - Pyrotechnic signal
C - Smoke signal
D - None
E - Other

Line 8 Patient Nationality and Status
A - US military
B - US citizen
C - Non-US military
D - Non-US citizen
E - Enemy prisoner of war

Line 9 NBC Contamination (only if applicable)
N - Nuclear
B - Biological
C - Chemical
* *Peacetime*: TERRAIN DESCRIPTION

Figure 13-4. The 9-line format is used to transmit requests for evacuation. Adapted from US Department of the Army. *Medical Evacuation*. DA; 2019. ATP 4-02.2.

and effective clinical practice. Starting from POI, clinical care should be recorded in paper documentation or electronic health records, including:

- TCCC card (see Figure 13-5).
- DD Form 3019 (Resuscitation Record).
- AF Form 3899 (PM Record used by AEC and ERCC teams).

Note: To ensure continuity of care, send all available documentation with the patient during PM. During TACEVAC, attach the TCCC card to the patient or hand it off to the receiving team.

Patient Care During Evacuation

Patient Stability

Assessing stability for flight is fundamental to medical regulation and ensures that evacuation is conducive to optimal patient outcomes.

- *Stable* patients are unlikely to require interventions beyond standard en route care capabilities and can withstand a bed-to-bed evacuation of up to 12 hours intratheater or 48 hours intertheater.
- *Stabilized* patients have secured airways, controlled bleeding, adequately treated shock, and immobilized major fractures. They may require emergency intervention during the evacuation but not surgical intervention.
- *Unstable* patients have fluctuating physiologic status with emergency and/or surgical intervention anticipated during evacuation.

Table 13-2 describes resuscitation goals for stabilizing a patient before transport. Patients validated for STRATEVAC must be stabilized. However, achieving stabilization goals before transport may not be possible in the far-forward environment. TACEVAC routinely moves inherently unstable patients, as clinical instability and the need for a higher level of care may be the reason for PM (eg, PM from POI to surgical resuscitation at Role 2 or PM from R2LM to Role 3 for stabilization before STRATEVAC). Additionally, evacuation of patients not considered adequately stabilized for PM may be required due to

TACTICAL COMBAT CASUALTY CARE (TCCC) CARD

BATTLE ROSTER #: _____

EVAC: ☐ **Urgent** ☐ **Priority** ☐ **Routine**

NAME (Last, First): _____ **LAST 4:** _____

GENDER: ☐ **M** ☐ **F** **DATE** (DD-MMM-YY): _____ **TIME:** _____

SERVICE: _____ **UNIT:** _____ **ALLERGIES:** _____

Mechanism of Injury: (**X** all that apply)

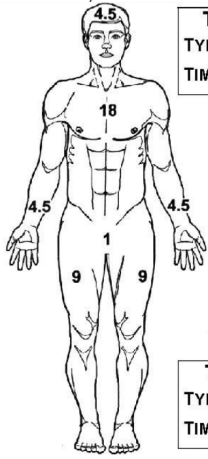
☐ **Artillery** ☐ **Blunt** ☐ **Burn** ☐ **Fall** ☐ **Grenade** ☐ **GSW** ☐ **IED**

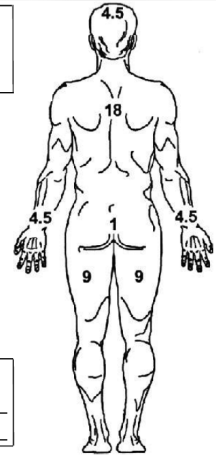
☐ **Landmine** ☐ **MVC** ☐ **RPG** ☐ **Other:** _____

Injury: (Mark injuries with an **X**)

TQ: R Arm
TYPE: _____
TIME: _____

TQ: L Arm
TYPE: _____
TIME: _____





TQ: R Leg
TYPE: _____
TIME: _____

TQ: L Leg
TYPE: _____
TIME: _____

Signs & Symptoms: (Fill in the blank)

Time				
***Pulse** (Rate & Location)*				
Blood Pressure	/	/	/	/
Respiratory Rate				
Pulse Ox % O2 Sat				
AVPU				
***Pain Scale** (0-10)*				

DD Form 1380, JUN 2014 **TCCC CARD**

Figure 13-5. The Tactical Combat Casualty Care card (DD Form 1380) is used in coordination with patient assessment at point of injury to document a Mechanism of Injury, Injuries, Signs & Symptoms, Treatments (MIST) report as well as patient demographics and any other pertinent information.

BATTLE ROSTER #: _____

EVAC: ☐ **Urgent** ☐ **Priority** ☐ **Routine**

Treatments: (X all that apply, and fill in the blank) ***Type***

C: TQ- ☐ **Extremity** ☐ **Junctional** ☐ **Truncal** _____

Dressing- ☐ **Hemostatic** ☐ **Pressure** ☐ **Other** _____

A: ☐ **Intact** ☐ **NPA** ☐ **CRIC** ☐ **ET-Tube** ☐ **SGA** _____

B: ☐ **O2** ☐ **Needle-D** ☐ **Chest-Tube** ☐ **Chest-Seal** _____

C:

	Name	***Volume***	***Route***	***Time***
Fluid				
Blood Product				

MEDS:

	Name	***Dose***	***Route***	***Time***
Analgesic (e.g., Ketamine, Fentanyl, Morphine)				
Antibiotic (e.g., Moxifloxacin, Ertapenem)				
Other (e.g., TXA)				

OTHER: ☐ **Combat-Pill-Pack** ☐ **Eye-Shield (**☐ **R** ☐ **L)** ☐ **Splint**
☐ **Hypothermia-Prevention** **Type:** _____

NOTES:

FIRST RESPONDER
NAME (Last, First): _____ **LAST 4:** _____

DD Form 1380, JUN 2014 (Back) **TCCC CARD**

Figure 13-5 *cont*. Reproduced from Department of Defense Forms Management Program. Accessed October 28, 2022. https://www.esd.whs.mil/Directives/forms/dd1000_1499/

operational factors that outweigh clinical factors. In these cases, ERCC personnel should be used for PM, if available, to provide continued resuscitation during PM to the nearest appropriate MTF.[9]

Note: Patients with rapidly changing clinic status and care requirements beyond standard en route care capabilities require augmentation with ERCC.

When moving unstable and recently stabilized patients, en route care is essential to PM, and the CCDR or PMRC will decide to augment MEDEVAC or AE with critical care assets. The US Army MEDEVAC is supported by critical care trained flight paramedics and can be augmented with en route critical care nurses (ECCN). TACEVAC missions can be further augmented with CCATT and medical attendants, including flight surgeons with the special operations medical element. The AE system is

Table 13-2. Suggested Resuscitation Goals for Stabilizing a Patient Prior to Flight

Clinical parameter	Resuscitation goal
Heart rate	50-120 beats/min
Systolic blood pressure	>90 mm Hg
Temperature	>95 °F (35 °C)
Hemoglobin	>8.0 g/dL
Platelets	>50 k/mm^3
INR	<2.0
Base deficit	<6
Lactate	<2.5 mmol/L

INR: International normalized ratio
Adapted from Joint Trauma System Clinical Practice Guidelines website. Interfacility Transport of Patients Between Theater Medical Treatment Facilities (CPG ID: 27). Accessed October 31, 2022. https://jts.health.mil/assets/docs/cpgs/Interfacility_Transport_of_Patients_between_Theater_Medical_Treatment_Facilities_24_Apr_2018_ID27.pdf

routinely augmented with CCATT and can be further supported by medical attendants for specialized missions and unique patient populations.

Note: Due to resource limitations, PC casualties are more likely to be under-resuscitated and not completely stabilized, so sending facilities should consider requesting PM augmented with critical care paramedics, an ECCN, or ERCC teams.

Stressors of Flight

The aeromedical environment introduces stressors not present during patient care on the ground. Stressors include the effects of decreased barometric pressure at altitude and the impact of the operational environment inherent to PM on an aircraft. Understanding the stressors of flight and mitigating their impact on a patient's condition decreases the risk of deterioration en route. Efforts to anticipate these stressors should start on the ground before evacuation.

Note: PC casualties are more likely to be under-resuscitated without advanced surgical or medical care and are more prone to deterioration from stressors of flight.

Effects of Altitude on Patient Care

Hypoxia. The risk of hypoxia at altitude is of particular concern. Oxygen delivery across the alveoli depends on a gradient with a higher partial pressure of oxygen (Po_2) in the surrounding air. As altitude increases, Po_2 decreases, and this alveolar gradient lessens, making oxygen delivery less efficient (a typical C-17 cabin is pressurized to 8000 ft with a Po_2 of 119 mm Hg compared to Po_2 of 160 mm Hg at sea level).[10,11] Therefore, higher amounts of supplemental oxygen are required to avoid hypoxemia. However, it is not always possible to match preflight ground oxygen requirements at altitude. For example, if a patient requires FIO_2 >75% at sea level, an equivalent Po_2 cannot be achieved at a cabin altitude of 8000 feet, even with FIO_2 of 100%. For this reason, a patient already on high oxygen settings at sea level may not tolerate air evacuation.

Note: Consider consulting with the ECMO team for mechanically ventilated patients with requirements of F_{IO_2} ≥70% and PEEP ≥14.

Gas Expansion. Boyle's law states that gas expands as barometric pressure decreases, and gas expansion is a significant concern for AE. For example, with gaseous volumes increasing by 52% at 8000 feet compared to sea level, a small pneumothorax at sea level can expand and become a tension pneumothorax at altitude.

Note: Due to expected expansion, trapped gas within the body (eg, pneumothorax) should be decompressed. If there are contraindications to decompression, or it is otherwise not feasible (eg, pneumocranium or pneumomediastinum), a cabin altitude restriction (CAR) may be required.

Cabin Altitude Restriction. A CAR can decrease the effects of low barometric pressure, particularly hypoxia and gas expansion, during PM at altitude. For instance, a CAR of 5000 feet would have a lower risk of hypoxia (a P_{O_2} of 133 mm Hg) and less gas expansion (only a 20% increase in volume compared to sea level). This effect also occurs with PM on rotary wing platforms, which are generally unpressurized but fly at much lower altitudes than a fixed wing and can transport inherently unstable patients while minimizing altitude impacts. A CAR can be requested when the PMR is submitted to PMRC. Additionally, the validating flight surgeon may identify this need (eg, a 5000 ft CAR is typical for all traumatic brain injury patients to avoid hypoxia), or CCATT may request one if required for patient care (eg, acute respiratory distress syndrome with high F_{IO_2} requirements).

Humidity. Relative humidity decreases with increasing altitude, which results in more significant insensible losses for all AE patients and increases oral or IV hydration requirements. Additionally, humidification of supplemental oxygen is necessary to avoid airway drying and complications such as epistaxis and mucous plugging. The low relative humidity is of particular concern to mechanically ventilated patients and is addressed using devices such as heat and moisture exchangers.

Temperature. Prevent hypothermia during fixed-wing and rotary-wing transport. Active warming with a Hypothermia Prevention and Management Kit (North American Rescue LLC) and administration of warmed fluids or blood products are preferred. However, if these interventions are unavailable, use passive warming with blankets or sleeping bags or cover the patient with whatever is available. Aircraft have varying thermal profiles for fixed-wing transport, and temperature management may dictate patient placement. For example, aft placement in a C-17 is generally colder than forward placement. Cabin temperature and patient placement are usually within the control of the AEC in coordination with the pilot and loadmaster on the aircraft.

Effects of the Operational Environment on Patient Care

Noise and Vibration. Noise and vibration are additional considerations for patient care in a transport environment, including ground, rotary, and fixed-wing platforms. Hearing loss results from prolonged exposure to high noise levels, and cruise noise ranges from 80 to 110 dB on the three primary AE aircraft (C-17, C-130, and KC-135).[10] Additionally, various frequencies of mechanical vibration can resonate and affect human tissues. Such vibrations may increase pain, particularly with fractures.

Note: Provide hearing protection for all patients before transport to mitigate hearing loss from prolonged exposure to high noise levels.

Note: PC teams should stabilize fractures with splints or external fixators before transport. Casts should be bivalved due to concern for swelling. If traction is required, use fixed traction, such as a traction splint for femur fractures, as weighted traction is unsafe during transport. Apply extra padding to affected areas and avoid placing litter straps directly over musculoskeletal injuries.

Pain, Anxiety, and Delirium. Multimodal analgesia with non-opiate medications can provide adequate pain control and reduce the need for high doses of opiates, which are associated with an increased risk of respiratory depression.

Note: PC teams should optimize pain control before evacuation using a multimodal approach with opiate and non-opiate medications, including non-steroidal anti-inflammatory drugs, acetaminophen, and ketamine. Avoid high doses of opiates in patients with unstable vital signs or shock and non-intubated patients with the potential for respiratory or airway compromise.

Anxiety and delirium can contribute to pain and patient discomfort and are exacerbated during evacuation. Particularly during STRATEVAC and with severe illness, travel across time zones and loss of day/night differentiation due to the dark environment of the aircraft can induce delirium. Non-pharmaceutical interventions such as reorientating or maintaining normal sleep-wake cycles can reduce delirium; however, pharmaceutical intervention may be required in critically ill patients.

Note: Communicating frequently with patients and providing a preflight brief can help reduce anxiety.

Immobility. Prolonged immobility can be a significant factor during PM, especially for litter-bound and critically ill patients. Prophylactic measures to prevent venous thromboembolism, aspiration, gastric stress ulcers, and skin breakdown should be initiated before the flight when possible.

Note: The trauma population and immobilized patients are at high risk for venous thromboembolism and require chemical or mechanical prophylaxis if not contraindicated.

Note: Patients with coagulopathy, traumatic brain or spinal injury, significant burn injury, or gastrointestinal bleeding, who require mechanical ventilation, high-dose steroids, or NPO orders should receive stress ulcer prophylaxis.

Note: For mechanically ventilated patients, the risk of aspiration increases during PM. Use a headrest with the NATO litter unless there is a concern for spinal injury. If enteral feeding is initiated in these patients, a post-pyloric feeding tube is preferred to prevent aspiration in flight.

Note: When available, place foam litter pads under patients, pad pressure points, and provide wound care for pressure ulcers before PM, particularly for STRATEVAC.

Human and Systems Factors. Environmental factors, such as stressors of flight, affect not only patients but also medical personnel and their ability to provide care. Additionally, systems and human factors impact PC and evacuation teams, increasing the risk of human error. Examples include fatigue, stress, hunger, frequent handoffs, degraded communication, resource limitation, equipment difficulties, and a nonstandard clinical environment.[12] Awareness and mitigation of these factors, including process improvement and continuous standardized training, are paramount to safe and effective care.[13]

Note: Handoffs and care transitions from PC to PM are high-risk periods for human error. Be aware of systems and human factors affecting you or the team receiving the patient after PC.

Summary

PM is a multifaceted mission that evacuates combat casualties from POI to definitive care and is essential to operational success in the deployed environment. A combination of dedicated, designated, and opportune ground, air, and maritime transport assets with various medical teams specializing in patient evacuation link the echelons of casualty care in a seamless continuum. PC is required when there is a delay in PM along this continuum. An understanding of the PM system and its regulating authorities is essential for forward operating teams to ensure rapid and effective transfer of patient care. Additionally, an understanding of the stressors of flight and their mitigation strategies will aid PC teams in preparing patients for evacuation. PM represents the end of PC and is critical to minimizing morbidity and mortality from injury and illness. Effective PM is measured in lives saved and ultimately results in preserving military forces by evacuating, treating, and returning service members to duty.

The following resources will help prepare PC providers to facilitate a seamless continuum of care:

Patient Movement Publications

- ***US Army***
  - Medical Evacuation (ATP 4-02.2)
  - Casualty Evacuation (ATP 4-02.13)
- ***US Navy and Marine Corps***
  - Patient Movement (NTTP 4-02.2M/MRCP 3-40A.M7)
- ***US Air Force***
  - En Route Care and Aeromedical Evacuation Operations (DAFI 48-107v1)
  - En Route Critical Care (DAFI 48-107v2)
- ***Chairman of the Joint Chiefs of Staff***
  - Joint Health Services (JP 4-02)
- ***North Atlantic Trade Organization***
  - Allied Joint Doctrine for Medical Support (AJMedP-4.10)
  - Allied Joint Medical Doctrine for Medical Evacuation (AJMedP-2)
  - Forward Medical Evacuation (AAMedP-1.5)
  - Aeromedical Evacuation (AAMedP-1.1)

Clinical Resources for Patient Movement

- ***Clinical Practice Guidelines***
  - Joint Trauma System: jts.health.mil
- ***Tactical Combat Casualty Care***
  - Deployed Medicine: www.deployedmedicine.com

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Abbreviations and Acronyms

A

ABC: assessment of blood consumption; airway, breathing, circulation
ABCDE: airway, breathing, circulation, disability, exposure
ABG: arterial blood gas
ABO: blood groups (types A, B, AB, and O)
ACLS: advanced cardiac life support
ADVISOR: advanced virtual support for operational forces
AE: aeromedical evacuation
AEC: Aeromedical Evacuation Crew
AF: Air Force
AGAP: anion gap
AGE: acute gastroenteritis
AIDS: acquired immunodeficiency syndrome
AMS: altered mental status
AOE: austere and operational environment
A/P: active/passive
APRV: airway pressure release ventilation
ARDS: acute respiratory distress syndrome
ASBP: Armed Services Blood Program
ASM: all service members
AVPU: alert, verbal, pain, unresponsive

B

BG: blood glucose
BID: two times per day
BP: blood pressure
BUN: blood, urea, nitrogen
BVM: bag-valve-mask

C

Ca++: calcium ion
CAR: cabin altitude restriction
CASEVAC: casualty evacuation
CBRN: chemical, biological, radiological, nuclear
CCATT: Critical Care Air Transport Team
CCDR: combatant commander

CCP: casualty collection point
cHgb: capillary hemoglobin
Cl-: chloride anion
CLS: combat lifesavers
CNS: central nervous system
CO: cardiac output
CONUS: continental United States
CO_2: carbon dioxide
COVID-19: coronavirus disease of 2019
CPAP: continuous positive airway pressure
CPD: citrate-phosphate-dextrose
CPDA-1: citrate-phosphate-dextrose adenine
CPG: clinical practice guideline
CPOT: Critical Care Pain Observation Tool
CV: cardiovascular

D
dB: decibel
DC: direct care
DD: Department of Defense
D50: dextrose 50%
D5: dextrose 5%
D5LR: dextrose 5% lactated Ringer solution
DI: diabetes insipidus
DKA: diabetic ketoacidosis
DOD: Department of Defense
DO_2: oxygen delivery
DRI: daily reference intake
D10W: dextrose 10% in water
D25: dextrose 25%
DVT: deep vein thrombosis

E
ECCN: en route critical care nurse
ECG: electrocardiogram
ECMO: extracorporeal membrane oxygenation
EDV: end diastolic velocity
EFAST: extended focused assessment with sonography in trauma

EG: endothelial glycocalyx
EN: enteral feeding
EPAP: expiratory positive airway pressure
ERCC: En Route Critical Care Team
ERPSS: En Route Patient Staging System
ET: endotracheal
$EtCO_2$: end tidal carbon dioxide
ETT: endotracheal tube

F
FAST: focused assessment sonography for trauma
FDA: Food and Drug Administration
FDP: freeze-dried plasma
FIO_2: fraction of inspired oxygen
Fr: French gauge
FSR: First Strike Ration
FWB: fresh whole blood

G
GABA: gamma-aminobutyric acid
GCS: Glasgow Coma Scale
GI: gastrointestinal
GPMRC: Global Patient Movement Requirements Center
GRV: gastric residual volume

H
Hb: hemoglobin; also Hgb
HCID: high consequence infectious disease
HCO_3: bicarbonate
HCT: hematocrit
HFNC: high flow nasal cannula
Hg: mercury
Hgb: hemoglobin; also Hb
HIV: human immunodeficiency virus
HME: heat moisture exchanger
HOB: head of bed
HR: heart rate
HSS: health service support
Hz: hertz

I
IBW: ideal body weight
ICP: intracranial pressure
ICU: intensive care unit
iEPO: inhaled epoprostenol
IFR: inspiratory flow rate
IgM: immunoglobulin M
IM: intramuscular
IN: intranasal
iNO: inhaled nitric oxide
INR: international normalized ratio
IO: intraosseous
IPAP: inspiratory positive airway pressure
ISS: injury severity score
IU: international unit
IV: intravenous

J
JPMRC: Joint Patient Movement Requirements Center
JTS: Joint Trauma System

K
KCl: potassium chloride
KPhos: potassium phosphate
K+: potassium ion
killer B'S: bradycardia, bronchospasm, bronchorrhea, seizure

L
LC: local caregiver
LE: lower extremity
LMA: laryngeal mask airway
LOC: level of consciousness
LP: loading point
LPM: liters per minute
LR: lactated Ringers solution
LSCO: large-scale combat operations
LTOWB: low titer group O whole blood

M

MACE 2: Military Acute Concussion Evaluation 2
MAP: mean arterial pressure
MARCHPAWS: massive hemorrhage, airway, respirations, circulation/crisis standard of care/communication, hypo-/hyperthermia/head injury, pain control, antibiotics, wounds, and splints
MDI: metered dose inhaler
MDO: multidomain operations
MDRI: military dietary reference intake
MEDEVAC: medical evacuation
MFV: mean flow velocity
MIST: mechanism, injuries, signs/symptoms, treatment
MOI: mechanism of injury
MORE: modular operational ration enhancement
MP: medical personnel
MRE: Meal, Ready-to-Eat
MSK: musculoskeletal
MTF: military treatment facility
MUAC: mid-upper arm circumference

N

Na+: sodium ion
NATO: North Atlantic Treaty Organization
NG: nasogastric
NICU: neonatal intensive care
NMB: neuromuscular blockade
NMDA: N-methyl-D-aspartic acid
NPO: nothing by mouth
NS: normal saline
NSAID: nonsteroidal anti-inflammatory drug

O

OA: operational area
OG: orogastric
OGA: other government agency
ONSD: optic nerve sheath diameter
OP: organophosphate
ORS: oral rehydration solution
OTFC: Oral transmucosal fentanyl citrate

P

PACE: primary, alternate, contingency, emergency
$PaCO_2$: partial pressure of carbon dioxide in arterial blood
PaO_2: partial pressure of arterial oxygen
PC: prolonged care
PCC: prolonged casualty care
PCO_2: partial pressure of carbon dioxide
PE: phenytoin sodium equivalents
PECC: Patient Evacuation Coordination Cell
PEEP: positive end-expiratory pressure
PERRL: pupils equal, round, reactive to light
PFC: prolonged field care
pH: negative log of the hydrogen ion concentration
PI: pulsatility index
PLTs: platelets
PM: patient movement
PMR: patient movement request
PMRC: Patient Movement Requirements Center
PO: per os
POC: point of care
POI: point of injury
PO_2: partial pressure of oxygen
pO_2: partial pressure of oxygen
Ppeak: peak pressure
Pplat: plateau pressure
PPI: proton-pump inhibitor
PR: per rectum
PRBC: packed red blood cells
PRN: as needed
PSV: peak systolic velocity
PT: prothrombin time

R

RASS: Richmond Agitation Sedation Scale
RBCs: red blood cells
RDD: radiological dispersal device
RE: remote expert
ReSoMal: rehydration solution for malnutrition
RI: resistivity index

ROM: range of motion
RP: relay point
RR: respiratory rate
RT: room temperature
R2E: Role 2 enhanced
R2LM: Role 2 light maneuver
RUSH: rapid ultrasound for shock and hypotension
RV: right ventricle
Rx: a medical prescription

S
SAM: severe acute malnutrition
SaO_2: oxygen saturation (blood gas)
SBP: systolic blood pressure
SGA: supraglottic airway
SI: shock index
SIADH: syndrome of inappropriate anti-diuretic hormone
SLUDGE: salivation, lacrimation, urination, defecation, increased gastric mobility, emesis
SO_2: sulfur dioxide
SOB: shortness of breath
SOF: Special Operations Forces
spO_2: peripheral capillary oxygen saturation
SQ: subcutaneous
S/S: signs and symptoms
STRATEVAC: strategic evacuation

T
TACEVAC: tactical evacuation
TBI: traumatic brain injury
TBSA: total body surface area
TCCC: tactical combat casualty care
TCD: transcranial Doppler
THOR: trauma hemostasis and oxygenation research
TID: three times per day
TIVA: total intravenous anesthesia
TMDS: Theater Medical Data Store
tPA: tissue plasmin activator
TPMRC: Theater Patient Movement Requirements Center

TPR: temperature, pulse, respiration
TRAC2ES: TRANSCOM Regulating and Command & Control Evacuation System
TTD: transfusion transmitted diseases
TV: tidal volume
TXA: tranexamic acid

U
UA: urinalysis
UGR: unitized group ration
UOP: urine output
US: United States
USAISR: United States Institute of Surgical Research
USTRANSCOM: United States Transportation Command

V
VBG: venous blood gas
VEE: Venezuelan equine encephalitis
VHF: viral hemorrhagic fevers
V_t: tidal volume
VTC: video teleconference
V-V ECMO: veno-venous extracorporeal membrane oxygenation

W
WB: whole blood
WBC: white blood cells
WG: working group
WHO: World Health Organization

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