Chapter 2

LESSONS LEARNED

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INTRODUCTION

This chapter summarizes some of the lessons learned from experiences in the Vietnam War (F. G. La P.) and the Persian Gulf War (T. H. M.). Our combined expertise in military ophthalmology—both the treatment of injured soldiers and the workings of the military medical system—leads us to believe that some of the same difficulties that the US military medical establishment experienced early in our nation's history continue to be repeated. Some of the hard-won lessons from our own experience and those from previous wars, which should be remembered by current and future generations of military ophthalmologists, include the following:

- Having experienced ophthalmologists at the forward echelons will ensure that our soldiers get the best possible initial and definitive care.
- Having a senior ophthalmologist in theater may ensure that (*a*) the concerns of all eye-care professionals are heard and (*b*) training of nonophthalmologists is accomplished.
- Hands-on inspection of supplies prior to deployment is mandatory to ensure that modern and usable equipment is available to treat the injured soldier.

If we do not learn from our predecessors, we will continue to make the same mistakes they did.

Allen Greenwood, MD (1866–1942), a prominent US ophthalmologist, volunteered his services in the Spanish–American War, volunteered again to serve in France during World War I, and became Senior Ophthalmic Consultant for the American Expeditionary Forces. At the end of that war, General Pershing cited him for exceptionally meritorious and conspicuous services. Greenwood's description of hospital conditions in France in 1918 underscores our first lesson, that experienced ophthalmologists must be deployed to forward echelons:

> I want to take a minute to draw a word-picture of an evacuation hospital in time of stress. During the height of the Argonne offensive I went to the most forward of the evacuation hospitals, at the tip of the forest, which had been opened only two days. It had been raining a week, was still raining when I arrived, and the roads were a sea of mud. The hospital was in an old chateau, with tents arranged around it, and practically every ambulance wheel went up to the hub in the mud. The nurses and officers were wearing rubber boots, and those that were there to help out or to see how things were going wore overshoes. I entered the hospital at three o'clock in the afternoon. Every ward was crowded. Ambulances were coming at the rate of one every two or three minutes. The officer who had charge of the shock ward had four tent wards filled with shock cases. Among these were ten or fifteen men whose faces were partly destroyed. I wish I had the gift of easy speech and the ability to draw word-pictures, so as to draw for you a real picture of that hospital—the rain coming down in torrents, the sea of mud, the shock ward filled, a little heater at the foot of each bed, with men looking at their last gasp, ambulances coming in every two or three minutes, and the drivers exhausted. About thirty miles away we had a special hospital for head cases, but it seemed a crime to ask the drivers and the patients to go the extra thirty miles to reach this eye hospital. This shows the *necessity of having a competent ophthalmic surgeon right at the spot to take care of such cases*" [emphasis added].[1]

What was true and vitally important in World War I remains even more so today, because—given the resources—today's ophthalmic surgeon with subspecialty expertise can salvage eyes that in past wars were inevitably lost, and therefore can increase the number of casualties returned to duty. As Spalding and Sternberg commented in 1990:

> The advent of microsurgery in the 1960's, leading to better closure of ocular lacerations, and the development of vitrectomy techniques in the 1970's, allowing successful repair of posterior segment wounds, have resulted in a dramatic improvement in the prognosis for patients with penetrating ocular injuries.[2]

The objective of this chapter is to specify exactly what theater of operations eye care (TOEC) should be and why. Its genesis lies in the preparation of the history of Army ophthalmology in the Vietnam War[3] and of the history of eye armor development,[4] in the review of reports of military ophthalmologists following World War I, World War II, the Korean War, and the Persian Gulf War, and in discussions with present and former military ophthalmologists of the Army, Navy, and Air Force. A radical revision of eye care provided at all four echelons within the theater of operations (TO) is required if the wounded are to receive optimal care.

The soldier who cannot see, cannot fight. Tiny fragments that produce minor if any disability when impacting elsewhere often produce incapacitating visual disability and, through sympathetic spasm

of the orbicularis oculi of the fellow uninjured eye, functional bilateral blindness. The incidence of eye injuries has increased from 0.5% in the American Civil War to 9% in the Vietnam War mainly because of the increasing use of munitions that produce myriad, small, metallic and nonmetallic fragments on detonation. Battlefield eye injuries frequently coexist with other serious and even life-threatening injuries. Other threats to the eye include blunt forces (eg, tree branches, rifle butts and barrels), blown sand and dirt, flechettes, laser wavelengths, blistering agents, heat, and, in the future, probably microwaves and particle beams.

In Vietnam, a soldier struck in the eye in combat had a 50% chance of losing the eye.[3] Only 25% of the Vietnam eye casualties studied by Tredici[5] could return to active duty, while 83% of all surviving wounded could do so.[6] Eye injuries are expensive for society at large as well as for the casualty, in that these patients will have a permanent disability and will need rehabilitation and job training.

Polycarbonate eye armor (Ballistic Laser Protective Spectacles [BLPS] and Special Protective Eyewear Cylindrical Surface [SPECS]) has been developed and improved over the last several decades. Studies have indicated that 2-mm-thick polycarbonate will prevent almost all blunt-force injuries and 39% of injuries caused by missiles.[7] Two of the threatening laser wavelengths will be defeated by a laser-protective attachment, and polycarbonate intrinsically provides significant protection from the carbon dioxide laser emitted wavelength. Unfortunately for the soldier's eye, conventional munitions are being improved, tunable dye lasers are in development, flechettes penetrate 2-mm-thick polycarbonate, and current eye armor provides no specific protection against microwaves or particle beams, so that eye injuries can be expected to occur, to be of great seriousness, and to demand expert and immediate care.

EYE CARE IN THE THEATER OF OPERATIONS

The principles that should govern the provision of medical care in the TO to the eye-injured and -diseased can be divided into two groups: the general and the specific. The general principles are expertise, immediacy, control, assertiveness, complexity, cooperation, integration, reassessment, innovation, and education, and are discussed below. The specific principles apply to the care of the injuries and diseases of the anterior and posterior segments of the globe, the ocular adnexa, and the bony orbit, and are expressed in the Practice of TOEC section of this chapter.

General Principles

There is no delayed primary closure in ophthalmic surgery. The first surgical procedure performed on the injured eye and/or its adnexa is almost always the definitive one, and it must be performed as soon after injury as possible. It therefore follows that we must be prepared to practice such definitive ophthalmic surgery in the TO. To do so requires the presence of ophthalmologists with subspecialty expertise in certain hospitals in the TO. Ophthalmology residents and physicians who have received on-the-job training (OJT) are never qualified to practice independently as ophthalmologists in the TO. Some argue that eye casualties who require vitrectomy and other sophisticated posterior segment surgical procedures can and should receive such care after being evacuated from the TO. They are wrong, because (1) we may not be able to evacuate our casualties from a TO soon enough to provide such care at the appropriate time after injury because of other nonocular injuries that render the patient nontransportable, or (2) the means for such evacuation may not be available. We cannot assume that we will always have air superiority. Therefore, we must be prepared to practice definitive vitreoretinal surgery in the general hospital (GH) (see the section on Practice of TOEC). Ophthalmologists in the TO hospitals must (1) be supported by nurses and corpsmen specially trained to assist in ophthalmic surgery and (2) be provided with necessary diagnostic and therapeutic instruments and supplies.

These principles were first enunciated in 1918 by American ophthalmologists who had served in Europe in World War I and have been reiterated by their successors following World War II, the Korean War, the Vietnam War, and the Persian Gulf War. If we continue to fail to provide early definitive ophthalmic surgery for our casualties, as occurred in World War II and the Korean, Vietnam, and Persian Gulf wars, we will continue to condemn them to preventable blindness.

Expertise

Army ophthalmologists who served in World War I, World War II, the Korean War, the Vietnam War, and the Persian Gulf War agree that the major

elements in the successful care of the eye injured are twofold: the expertise of the ophthalmologist providing such care, and the promptness with which it is provided. The US Army ophthalmologist who surveyed the provision of eye care by the British and French medical departments in 1917 and 1918 called for specially trained ophthalmic surgeons to serve in forward hospitals.[8]

As Wood stated in 1921, regarding the need for expert ophthalmological care near the front:

> In the American Expeditionary Forces ophthalmologists were finally stationed in most of the front line hospitals (casualty clearing hospitals) so that every ocular wound should receive attention at the earliest possible moment, the principle having become generally recognized by time of our entry into the war, that the golden opportunity in the treatment of traumatic corneal ulcers, penetrating and other wounds of the eye, as with all general wounds, lay between the moment of injury with its usual contamination and the time when simple contamination flamed into active infection. Further it has long been an ophthalmic axiom that the earlier the removal of intraocular foreign bodies the greater the chances of ultimate vision, and placing of these skilled men behind the front, backed by base hospitals and placed as far forward as possible and having radial control through their specialist chiefs, led accordingly to incalculable saving of vision and of life, as well as to the lessening of the final deformities in thousands of wounds.[9]

Vail expressed a similar thought in the official history of World War II:

> Experience showed that it would have been a wiser policy to *staff evacuation hospitals with the best ophthalmic talent available* rather than to concentrate it in the communication zone where, when the casualty was eventually received, there was not a great deal that even the most experienced ophthalmologist could do for him [emphasis added].[10]

In the early days of World War I, before ophthalmologists were fully functional in the combat zone, a great wastage of sight resulted from the enucleation of every perforated eye by general surgeons.[9] And the identical problem occurred at the onset of World War II.[11]

In the same vein, regarding the experience in World War II, Stone stated:

> [M]any traumatisms of the eye were unduly complicated by failure to treat the conditions properly at the time of the injury and in the period immediately thereafter.[12]

And King succinctly commented:

> The primary operation upon an eye is usually the definitive one and the surgeon seldom has a second chance. … [T]he complete examination which is necessary before surgery demands specialized equipment; this equipment and the small delicate instruments which are required for ocular surgery are not usually available to the general surgeon.[13]

To provide our wounded with the quality of care to which they are entitled, it is mandatory that ophthalmologists who possess subspecialty expertise provide such care at 3rd- and 4th-echelon hospitals in the TO. Ophthalmology has advanced so rapidly since the 1980s that clearly defined subspecialties have emerged, each requiring 1 or more years of fellowship training and near-exclusive concentration on them by their practitioners. The results of subspecialization have been (1) a dramatic improvement in the diagnosis and management of ocular and ocular adnexal injury and disease, and (2) the disappearance of the general ophthalmic surgeon, for no one can master all types of ophthalmic surgery. The ophthalmic subspecialties most needed in the TO are those of the

- anterior segment (cornea/lens),
- posterior segment (vitreoretinal), and
- ocular adnexa (ocular plastic surgeon).

This matter will be considered in detail in the Practice of TOEC section. We must plan to put our best ophthalmic surgeons (Regular Army and Reserve) who possess subspecialty expertise in the TO and not keep them, for the most part, within the continental United States (CONUS), as was done during the Vietnam War.

Immediacy of Treatment

Any number of people have recognized that the sooner combat casualty care is given, the better the outcome for the patient, including the American College of Surgeons' Committee on Trauma:

> The most significant ingredient necessary for optimal care of the trauma patient is commitment, both personal and institutional. For the institution, optimal care means providing capable personnel who are immediately available. It also implies using sophisticated equipment and services that are frequently expensive to purchase and maintain. It means there must be a priority of access to sophisticated laboratory and radiologic facilities as well as to the operating suites and intensive care units.[14]

As with all serious injuries, the outcome following eye injury is directly related to the rapidity with which expert care is provided. Bellamy's comments regarding lifesaving surgery in World War II apply to sight-saving surgery, as well:

> [E]mphasis … [was] … placed upon providing lifesaving surgery far forward on the battlefield. During the North African campaign of 1942–1943 it was recognized that evacuation of the seriously wounded to hospitals in the rear without first performing needed surgery was associated with an unacceptably high mortality. The problem was successfully solved by attaching to clearing companies and evacuation hospitals near the front ad hoc units able to provide surgical care for casualties with trunk and serious extremity wounds.[15]

This principle of immediacy is most applicable in the management of severe posterior segment (retina, vitreous, choroid, and sclera) injuries, for it is now established that such injuries must be managed surgically as soon as possible,[16,17] and that the speedy repair of a retinal detachment decreases the incidence of proliferative vitreoretinopathy—a major cause of treatment failure. Corpsmen and general medical officers must be capable of detecting eye and ocular adnexal injuries, making an initial assessment of their significance, rendering appropriate care, and arranging for evacuation to the ophthalmologist (Figures 2-1 and 2-2). Skilled ophthalmologists must be available at 3rd-and 4th-echelon hospitals to provide expert definitive care as soon as possible after injury (Figures 2-3 and 2-4).

Fig. 2-1. Aeromedical evacuation helicopter. Air superiority and the ability to evacuate critically injured patients by air has resulted in faster delivery of definitive repair to our soldiers on the modern battlefield. Photograph: Courtesy of Albert Hornblass, MD, Major, Medical Corps, US Army (Ret), New York, NY.

a

b

Fig. 2-2. (**a**) After performing the evaluation of airway, breathing, and circulation, the triage officer evaluates all body systems. (**b**) Examination of the eye, adnexa, and orbit must be done by the ophthalmologist in an expeditious but thorough manner to determine the extent of ocular injuries and establish the priority of surgical repair of these injuries. This information is then conveyed back to the triage officer. Reproduced with permission from La Piana FG, Hornblass A. Military ophthalmology in the Vietnam War. *Doc Ophthalmol*. 1997;93:39.

Such care may include, in addition to a full ophthalmic examination, additional diagnostic procedures (eg, ultrasonography, computed tomography [CT] scan), surgical repair, and initiation of antibiotic therapy. The ophthalmic surgeon will frequently work as a member of a head and maxillofacial trauma team and should be as familiar as possible with the procedures of neurosurgeons and maxillofacial surgeons (Table 2-1 and Figures 2-5 through 2-7). Edwards's comments, published in 1954, are highly relevant:

> At the beginning of the [Korean] war, definitive surgery was done mostly at Tokyo Army Hospital and some at the hospital ship in Pusan. The time elapsed between injury and arrival at Tokyo was

Fig. 2-3. Eye Clinic, 24th Evacuation Hospital, Long Binh, Vietnam. A complete ophthalmology lane allows for definitive evaluation of eye injuries. The complete eye lane must have at a minimum a slitlamp and an indirect ophthalmoscope. Reproduced with permission from La Piana FG, Hornblass A. Military ophthalmology in the Vietnam War. *Doc Ophthalmol.* 1997;93:40.

Fig. 2-4. Third- and 4th-echelon facilities have operating room capabilities. Often, the ophthalmologist will have to manage the patients with multiple injuries in coordination with a neurosurgeon or otolaryngologist. Photograph: Courtesy of William Dale Anderson, MD, Major, Medical Corps, US Army (Ret), Colorado Springs, Colo.

> often in excess of 24 hours. We found that the patients operated on by an ophthalmologist aboard the ship arrived in better condition at Tokyo than those who came directly, thus indicating the need for earlier surgery. For this reason, ophthalmologists were pushed forward into evacuation hospitals in Korea. Thereafter, definitive treatment could be given in 6 to 8 hours from even the most distant portions of the front line. In the opinion of everyone, the end-results justified this system. Thus, in the light of the experience in both wars, it is recommended that ophthalmologists be placed as far forward as possible, depending on their availability, to enable preoperative time lags of less than 12 to 18 hours.[13]

A major objective of TOEC is to maximize the number of casualties who can return to duty within the theater. Many eye and ocular adnexal injuries are initially incapacitating but—if managed expertly and promptly by ophthalmologists, with the requisite personnel, support, and equipment—can heal or at least stabilize rapidly enough to permit the patient's return to duty. If inappropriately managed, however, many will progress to a condition necessitating evacuation from the TO and perhaps ultimate retirement for medical disability. Corneal lacerations, hyphemas, blowout fractures of the orbit, and major lid and tear-duct lacerations are examples of such injuries.

TABLE 2-1

CONCOMITANT INJURIES ASSOCIATED WITH OCULAR TRAUMA* DURING THE KOREAN WAR

Other Injuries	Number and Percentage of Associated Ocular Injuries
Facial	42 (15%)
Maxillofacial	47 (16%)
Neurosurgical	32 (11%)
Thorax	6 (2%)
Abdomen	3 (1%)
Extremities	48 (17%)
None	59 (21%)
Unknown	49 (17%)
TOTAL	286 (100%)

*Attention is invited particularly to the 32 eye injuries that were seen in conjunction with neurosurgical injuries and to the 47 eye injuries with associated maxillofacial wounds.
Reproduced from King, Edwards. *Recent Advances in Medicine and Surgery*. US Army Medical Service Graduate School, Army Medical Center [now Walter Reed Army Medical Center], Washington, DC: 1954: 477–478, 481.

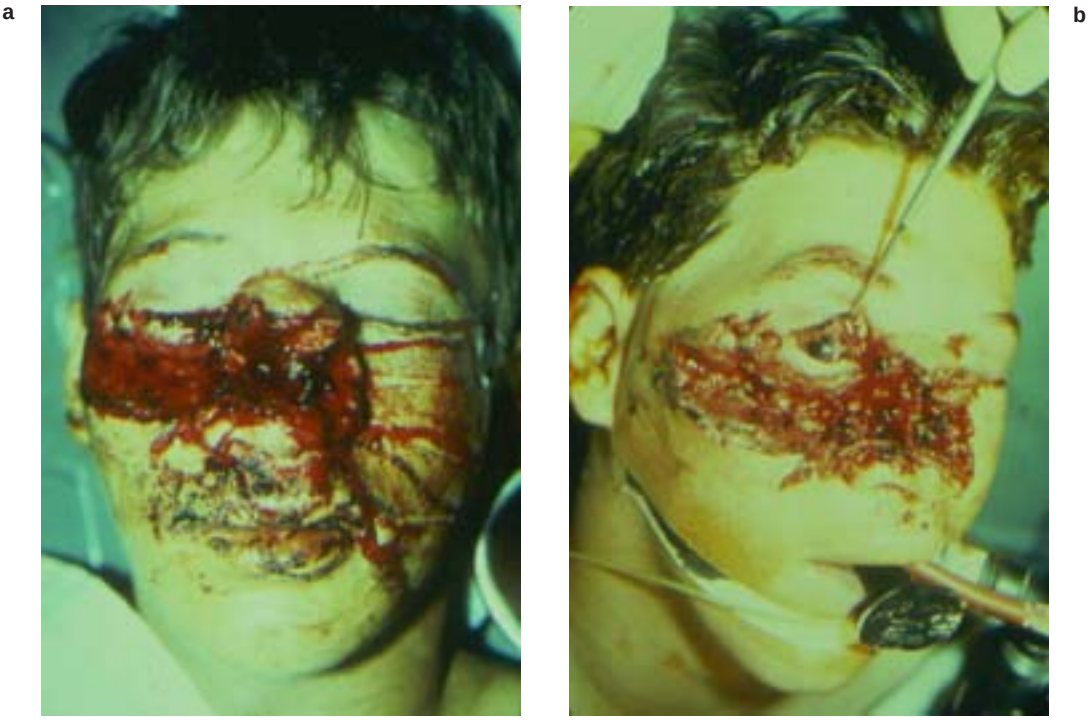

Fig. 2-5. During the Vietnam War, this soldier, having suffered severe midface and eye injuries, was seen (**a**) at the time of triage and (**b**) in the operating room.

Control of Medical Resources

The need for control of Army Medical Department (AMEDD) resources by AMEDD personnel is agreed on by all. An extension of this principle to the conduct of ophthalmology in the TO is necessary, because only a senior ophthalmology consultant possesses the understanding required for the appropriate allocation and utilization of resources. There is ample historical support for this principle. Based on experiences gained in World War I, it was recommended that the chief consultant in a specialty should not only supervise treatment but also

> give wise advice, instruction and actual demonstrations as to the best and most efficacious methods of treatment, in order that the work of his department may *conform to the recognized and accepted standards of the best civil and military practice* [emphasis added].[8]

This report also commended the Eye Centers of the British Expeditionary Forces under the British Medical Service for their efficiency, equipment, and organization, especially the appointment of one ophthalmic surgeon to supervise and coordinate

Fig. 2-6. A gunshot wound to the orbit has caused severe damage to this soldier's globe and adnexa during the Vietnam War. Ophthalmologists at the 3rd and 4th echelons must be prepared to treat patients with severe injuries of the globe and surrounding structures.

a

b

Fig. 2-7. Multiple fragmentation wounds (**a**) before and (**b**) after preparation for surgical repair. Fragments that may barely penetrate the superficial layers of the skin have the potential to cause severe damage to the eye. Photograph a: Reproduced with permission from Wong TY, Seet B, Ang CL. Eye injuries in twentieth century warfare: A historical perspective. *Surv Ophthalmol*. 1997;41:452. Photograph b: Courtesy of William Dale Anderson, MD, Major, Medical Corps, US Army (Ret), Colorado Springs, Colo.

services for the entire force.

Based on experience gained in World War II, the US Army official history recommends that in the event of the outbreak of future hostilities,

1. [a] Consultant in Ophthalmology should at once be placed on active duty in the Office of the Surgeon General, and
2. [u]pon the activation of each Overseas Theatre, a Consultant in Ophthalmology should at once be placed on duty and made responsible for ophthalmic programs within the theatre.[18]

Speaking of the lack of a consultant in ophthalmology throughout the US military in World War II, Vail stated:

> The chief fault of the past was the delay in setting up the position of chief consultant in ophthalmology in the office of the Surgeon General of the Army. The Navy never has such an officer; and the Air Force, even in those days, was a law unto itself. All of these errors and much of the waste could have been prevented by a skilled and experienced ophthalmologist with appropriate rank and authority placed in the offices of the Surgeon General of the various forces. At the present time there is no such officer any place.[19]

Apparently, however, some improvement was evident during the Korean War:

> The advice of Consultants was given great weight in matters of assigning personnel as well as of maintaining high caliber of medical care. The system worked out very well in Korea and should be continued in the future.[13]

In Vietnam, the Consultant in Ophthalmology to the Military Assistance Command Vietnam (MACV) Surgeon was usually the ophthalmologist of the 24th Evacuation Hospital (EH) (Figure 2-8). This ophthalmologist was, most of the time, a relatively junior officer and too busy to function as a true senior consultant and to effect necessary changes. On the outbreak of hostilities, a senior Army ophthalmologist should be assigned as the Consultant in Ophthalmology on the Theater Army Surgeon's/Medical Brigade Commander's staff. This individual should directly and personally oversee all aspects of planning for and practice of ophthalmology within the theater. This individual and the Con-

Fig. 2-8. Doctor's quarters at the 24th Evacuation Hospital in the Republic of Vietnam (1968–1969). Photograph: Courtesy of William Dale Anderson, MD, Major, Medical Corps, US Army (Ret), Colorado Springs, Colo.

sultant in Ophthalmology to The Surgeon General must be experienced in both military medicine and ophthalmology, and work closely together.

The senior Army ophthalmology consultants should be selected on the basis of their proven ability to perform their jobs (as are chiefs of staff of the Army and hospital commanders) and not simply on the basis of seniority. The consultant should

- have operational control of all ophthalmic and optometric resources within the TO;
- be responsible for, and personally supervise the care of, the eye-injured and diseased—not only by the ophthalmologists and optometrists but also by all who render such care (other medical corps officers, corpsmen, and nurses);
- understand the pertinent aspects of geographic ophthalmology in the theater (endemic/epidemic diseases);
- interact effectively with his Navy and Air Force counterparts in patient care and evacuation matters;
- see to the proper orientation of new arrivals to the theater and proper utilization of OJTs;
- control the distribution and use of K-teams (potentially the ophthalmic equivalent of the Auxiliary Surgical Groups of World War II), if employed[15]; and
- oversee the operation of a registry of eye diseases and injury that should immediately be established on formation of the theater force.

The importance of the establishment and maintenance of such a registry is evidenced by the great value of data concerning eye injuries and disease collected during World War II[20] and by the costs of the relative failure to acquire such data for eye injuries in Vietnam.

Assertiveness

AMEDD considers ophthalmology to be a constituent of surgery, and this subordination is expressed at all levels. Because many Army surgeons—like most physicians—know little and care less about the eye and think of ophthalmologists as little more than optometrists who perform cataract surgery, ophthalmology has often not been provided the attention and resources it requires to most effectively execute its missions. Therefore, Army ophthalmologists must assertively compete for resources, educate their fellow physicians, and plan for the provision of eye care to the war casualty—who otherwise will continue to be condemned to preventable blindness. Military ophthalmologists must make themselves the preventive medicine officers for the eye, working to diminish risks of injury by promoting (*a*) safe practices both on and off duty and (*b*) the wearing of eye armor during the conduct of all eye-hazardous activities (see Chapter 26, The Development of Eye Armor for the American Infantryman). In general, the wearing of hard and soft contact lenses in the combat zone must be discouraged, because contact lenses enhance the likelihood of eye infections.[21] Military ophthalmologists must also be assertive in the prevention and management of ocular malingering, as manifested by gazing at the sun (solar maculopathy) or breaking the eyeglasses.

Complexity of Injuries

Eye injuries in a civilian setting in peacetime can profitably be compared with those produced by war. Whereas in peacetime, few ocular structures are injured and few coexisting injuries occur, the picture is quite different in wartime (Table 2-2), when eye injuries tend to be multiple, averaging about two per eye. Cohen[22] analyzed 281 cases of severe globe injury sustained in Vietnam and subsequently treated at Fitzsimons Army Medical Center (FAMC) between 1967 and 1970. He found that the 133 eyes (47% of the total) that remained in situ on presentation to FAMC had a total of 277 injuries, for an average of 2.1 injuries per eye. Likewise, analysis of 57 patients evacuated from Vietnam to Walter Reed Army Medical Center Ophthalmology Service from May 1968 to September 1969 showed that those patients sustained 100 injuries to the globe and/or ocular adnexa, an average of 1.8 injuries per eye.[3]

TABLE 2-2

OCULAR INJURIES SEEN IN WARTIME VS IN A PEACETIME EMERGENCY DEPARTMENT

Injuries	Wartime	Peacetime
Ocular Structures Injured	Several	Few
Number of Patients	Multiple	Usually one
Coexisting Injuries	Very often	Usually not
Time Available to Provide Care	Limited	Unlimited
Stress on the Surgeon	Severe	Moderate

Cooperation Among Specialists

Most ophthalmic surgery in peacetime is performed without the need for support from other surgeons. Military ophthalmologists caring for war casualties, however, must often work intimately with other surgeons because of many casualties' multiplicity of injuries. Because of such combined injuries, ophthalmologists should be co-located with neurosurgeons and maxillofacial surgeons. The ophthalmologist will work not only with neurosurgeons, otolaryngologists, and plastic surgeons, but also with orthopedic and general surgeons. Thus, military ophthalmologists should participate in courses dealing with the management of war casualties (eg, the Combat Casualty Care course, which includes both the C-4 course and the American College of Surgeons' Advanced Trauma Life Support [ATLS] course) and seize every opportunity to participate in the care of patients with midface trauma.

Reassessing, Updating, and Integrating With Other Plans

Plans for TOEC must be periodically reassessed because (*a*) weaponry, tactics, and, therefore, threats change and (*b*) better means of preventing and caring for eye injuries and disease will be developed and need to be integrated into the plan. Breakthroughs in both prevention and therapy must be immediately identified by military ophthalmologists and exploited for the benefit of service personnel.

Planning for TOEC must be fully integrated with general AMEDD planning to ensure that the mission is accomplished while resources are conserved. Military ophthalmologists must participate actively at all levels in AMEDD planning for TO casualty care.

Continuing Military Medical Education for Ophthalmologists

Education of all those who practice TOEC is a continuing obligation of the military ophthalmologist. Civilian ophthalmologists must also be kept aware of the plans for TOEC so they can help implement them, if necessary. The Tri-Service Ocular Trauma Course currently provides such education for active duty military ophthalmologists of the Army, Navy, and Air Force and could be expanded to include civilian ophthalmologists. All military ophthalmologists should attend the Tri-Service Ocular Trauma Course, preferably first in their senior year of residency and then at 3-year intervals. Through lectures and practical sessions, this course attempts to familiarize the student with the realities of practice in a TO and also facilitates exchange of information and joint planning by representatives of the Army, Navy, and Air Force.

In addition, a 4-hour block of instruction in the detection, diagnosis, and management of ocular and ocular adnexal trauma is given the fourth-year medical students at the Uniformed Services University of the Health Sciences. This course provides a base of knowledge that medical officers can build on.

Instruction of all eye-care providers is a major and continuing responsibility of all military ophthalmologists and its accomplishment should be a direct responsibility of the theater Army ophthalmologist. Nonophthalmologists (physicians, physician assistants, and corpsmen) should receive instruction that is similar to or, if possible, identical to that presented in the ATLS manual.

Specific Principles

The practice of TOEC, including evacuation of eye casualties, takes place at each of the four echelons of care.

1st and 2nd Echelons: Initial Care of Ocular and Ocular Adnexal Injuries

It is mandatory that eye injuries be properly managed by those caring for the patient *before* he or she reaches an ophthalmologist. The "patch and ship" policy exacerbates morbidity. Corpsmen, physician assistants, and physicians at all echelons of care within the theater must be taught what *must* and *must not* be done for the eye-injured patient at the site of injury, during evacuation, at the battalion aid station, and at hospitals not having an ophthalmologist assigned. The person providing the casualty's initial care must inspect the eyes and adnexal structures for injuries, and detect such injuries; at least develop a differential diagnosis and make a diagnosis, if possible; and render appropriate management. All of this must be performed in such a manner that no additional injury is induced either by the care provider himself or by those who render subsequent care (eg, during ground ambulance or helicopter evacuation). The relevant instruction included in the 1988 revision of *Emergency War Surgery,*[23] the *ATLS Manual*[24] and the 1991 *Combat Casualty Guidelines: Operation Desert Storm*[25] is a

EXHIBIT 2-1

RECOMMENDATIONS FOR INITIAL CARE OF OCULAR AND ADNEXAL INJURIES AT THE 1ST AND 2ND ECHELONS

1. Do not "patch and ship." Get visual acuity and history of the injury.
2. Inspect eyes and adnexal structures using bent paper clips, if necessary.
3. Detect injuries without further injuring the globe. Look for blood in the anterior chamber, lens dislocation, iris disinsertion, blood in the vitreous, retinal detachment, and retained intraocular foreign body (IOFB). A black reflex often indicates the presence of an intraocular hemorrhage. Palpate for discontinuity of the orbital rim and detachment of the medial canthal tendon.
4. Remove nonimpaled conjunctival FBs (using irrigation or a wet cotton-tipped applicator stick) and impaled-lid FBs that can contact the globe.
5. Do not remove impaled conjunctival (intraocular or intraorbital) FBs, but rule out intracranial injuries.
6. Irrigate corneal FBs, and wipe them off the cornea with an applicator stick, if necessary. Apply a broad-spectrum ophthalmic antibiotic ointment and a tight patch.
7. Treat corneal abrasions with a broad-spectrum antibiotic ointment and a tight patch if the patient is not a contact lens wearer. Patients who do wear contact lens have a higher risk of developing a corneal ulcer, so their abrasions should be treated with a broad-spectrum ophthalmic antibiotic ointment or solution and no patching. Do not use corticosteroids.
8. Identify a ruptured, penetrated, or perforated eyeball by edema of the conjunctiva, a shallow or deep anterior chamber, hyphema, decreased ocular motility, decreased visual acuity, or an intraocular hemorrhage (the inside of eye looks black or red). Apply a broad-spectrum ophthalmic antibiotic solution and a Fox or other rigid shield (no patch), and evacuate to a 3rd-echelon ophthalmologist. Apply no pressure to the eye, and ask the patient not to squeeze the lids.
9. Do not apply topical steroids.
10. Do not use ointment on an open eye.
11. Apply moist dressings on eyelid lacerations and medial canthal angle lacerations.
12. Do not attempt enucleation or evisceration (ie, no eye removal) at the 1st or 2nd echelons.
13. Use topical anesthesia *only* for examination purposes. Never give the patient the topical anesthetic for personal use, as self-medication can lead to a serious keratopathy.
14. For chemical burns, provide at least 60 minutes of irrigation and remove any particles from the cornea and conjunctiva, especially the fornices.
15. For white phosphorus burns, identify particles if necessary with 0.5% copper sulfate, and if possible, remove all particles under water.
16. For severe injuries, use tetanus prophylaxis and systemic antibiotics.
17. If intraorbital bleeding causes decreased visual acuity, perform a lateral canthotomy and cantholysis.
18. Tell patients with orbital fractures to refrain from nose blowing, and teach them how to stop sneezing by pressing hard just above the upper lip. If the sneeze cannot be stopped, they should not try to hold it in. Begin systemic antibiotics to cover sinus flora (ie, amoxicillin/clavulanate).
19. Consider repairing lacerations of the eyelid that involve the skin and muscle only without fat prolapse or involvement of the lid margin. Close the eyelid laceration with 6-0 silk.
20. Evacuate casualties with deeper lid lacerations and those involving the margin to a 3rd-echelon ophthalmologist.
21. Look carefully for lacerations of the canaliculi (tear ducts) and evacuate patients with such lacerations to a 3rd-echelon ophthalmologist. Apply a wet dressing on the injured area.
22. Keep orbital soft tissues moist in case of traumatic enucleation/partial exenteration and evacuate to a 3rd-echelon ophthalmologist.
23. Any further decrease in visual acuity after injury demands immediate evacuation to a 3rd-echelon ophthalmologist.
24. Treat laser burns of the cornea with topical ophthalmic antibiotics, patching, and daily examinations.
25. Evacuate casualties with laser burns of the retina to a 3rd-echelon ophthalmologist.
26. After any injury to the eyelids (eg, avulsion, thermal burns), keep the cornea covered. Any corneal exposure requires immediate evacuation to a 3rd-echelon ophthalmologist.

valuable introduction to and overview of this critically important subject. Some specific recommendations are listed in Exhibit 2-1.

The theater Army ophthalmologist should assume responsibility for the continuing education of all eye-care providers in theater. He or she must also work closely with those personnel responsible for aeromedical evacuation to assure that eye casualties are provided necessary in-flight care.

3rd and 4th Echelons: Evacuation to an Ophthalmologist

Pressure exerted on an eye that has been penetrated can extrude intraocular contents through the wound of entry and thereby convert a repairable injury to an irreparable one. Similarly, the administration of ointment to such an eye can result in passage of the ointment into the eye, where it does great damage. Therefore, *only* solutions of ophthalmic medications should be applied to an eye that might be penetrated, and all patients with such injuries must be evacuated wearing a Fox (aluminum) shield or a shield made of some semirigid material (eg, the bottom of a paper cup) over the injured eye. Severe eye injuries must receive an evacuation priority equal to that granted severe extremity injuries and second only to life-threatening injuries, because sight-saving care must rapidly, as well as expertly, be provided. Obviously, medical regulating officers must know at all times which hospitals in theater are prepared to provide care for eye casualties.

At 3rd- and 4th-echelon hospitals (Figure 2-9), the ophthalmologist should be a member of a "head and neck team," composed of a neurosurgeon, otolaryngologist, plastic surgeon, and oral surgeon, as experience in the wars of this century has clearly shown that combat casualty care is thereby optimized.

Definitive, expert, early care will be provided at the 3rd echelon for patients who have sustained an injury to the eye and/or ocular adnexal structures to expedite their return to duty or to save the globe. Watertight closure of the penetrated globe will enable subsequent additional stabilizing surgery to be performed at the 4th echelon. Lacerations of the eyeball, eyelids, and tear ducts will be closed primarily and immediately, utilizing a portable operating microscope. If necessary, the patient will subsequently be evacuated to the 4th echelon, where vitrectomy capability exists. Neurosurgeons and ophthalmologists will work together to decompress the optic nerve as necessary. Various injuries that may be encountered at the 3rd and 4th echelons (Figures 2-10 through 2-12) and sutures that I recommend for their repair are listed in Exhibit 2-2.

Fig. 2-9. The 3rd Field Hospital in Vietnam. Fourth-echelon hospitals are often in fixed facilities and should have full ophthalmic and head-and-neck capabilities.

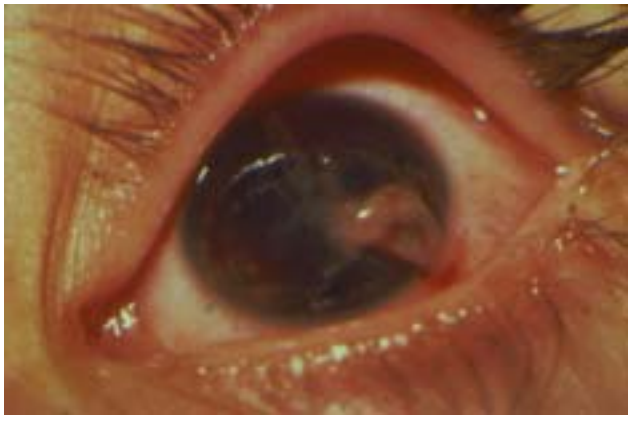

Fig. 2-10. A patient with an open globe with prolapse of uveal tissue needs immediate evacuation to an ophthalmologist for definitive repair of the corneal, scleral, or corneoscleral wound. Photograph: Courtesy of the late Richard M. Leavitt, MD.

Fig. 2-11. (**a**) The marked proptosis of the eye in this individual is due to a retrobulbar hemorrhage. Without prompt intervention, vision may be permanently lost. (**b**) Also of note is the blood in the mouth and the numerous facial lacerations. Photographs: Courtesy of Blackwell S. Bruner, MD, Potomac, Md.

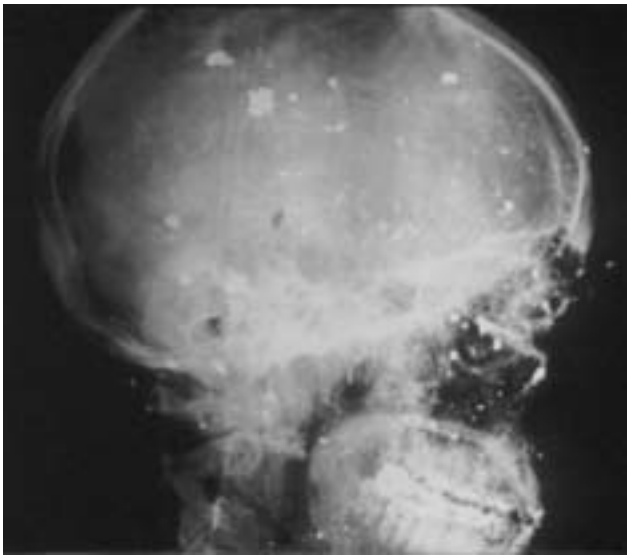

Fig. 2-12. Numerous metallic fragments are seen to involve the cranium and orbit on this lateral skull film (conventional radiograph). Fragmentation injuries commonly injure more than one organ system. Management of these casualties will involve the ophthalmologist for the eye and orbit, the neurosurgeon for the brain, and the otolaryngologist for the airway, sinuses, ears, and nose. Reproduced with permission from Wong TY, Seet B, Ang CL. Eye injuries in twentieth century warfare: A historical perspective. *Surv Ophthalmol*. 1997; 41:433–459.

Ultrasonography is required at the 3rd echelon for the detection and localization of intraocular foreign bodies (IOFBs) and retinal detachments. The portable operating microscope increases the speed of surgery by optimizing the view of the operative field, as well as enabling better surgical results, thereby decreasing ocular morbidity and increasing return to duty. The portable operating microscope can also be employed outside the surgical suite (eg, in the minor/outpatient surgical facility) for minor repairs and suture removal, and it can also be used by other surgeons. The suction/cutter should be available at the 3rd echelon to remove vitreous from the anterior chamber. Irrigation and aspiration of a cataractous lens will be performed only if the lens is ruptured and prolapsed or mixed with vitreous. Otherwise, patients with traumatic cataracts will be evacuated to the 4th echelon.

Surgical repair of eye and adnexal injuries can be performed concurrent with repair of other injuries. CT is necessary for the localization of intraocular and intraorbital foreign bodies (FBs) and for definition of orbital fractures. The CT scanner must be able to provide 1.5-mm cuts and coronal and sagittal reformats.

An eye clinic set is required wherever an ophthalmologist is assigned, as the specialized diagnostic instruments included therein (eg, slitlamp) are mandatory for the care of patients with eye injuries and diseases. The eye clinic should be able to perform minor surgery. Two ophthalmologists (one with anterior segment subspecialty expertise and

EXHIBIT 2-2

RECOMMENDED SUTURES FOR THE REPAIR OF VARIOUS ORBITAL AND ADNEXAL INJURIES

1. Close corneal lacerations with a 10-0 monofilament nylon.
2. Close scleral lacerations with 8-0 nylon, 8-0 silk, or 5-0 Mersilene, as determined by the size and location of the injury.
3. Repair orbital and adnexal soft-tissue lacerations with 4-0 and 6-0 chromic gut.
4. Repair extraocular muscle with 6-0 Vicryl.
5. Repair the medial canthal tendon with 4-0 Mersilene.
6. Close conjunctival lacerations with 6-0 plain gut.
7. Close adnexal skin with 6-0 silk.
8. Repair lid margin with 4-0 or 6-0 black silk suture through the tarsal plate (cut long so that it can be used as a traction suture), and 6-0 black silk suture at the anterior and posterior lid-margin borders.
9. Stent lacerated canaliculi and nasolacrimal duct with silicone tubing or a monocanalicular stent, to be left in place up to 6 months. Close the wound with 6-0 chromic and 6-0 or 8-0 silk sutures.

one with ocular plastic and adnexa subspecialty expertise) are required at the 3rd echelon, where they will be supported by three corpsmen who are trained to assist in ophthalmic surgery.

The ophthalmologists at the 4th echelon not only must be able to handle all the injuries that are usually seen at the 3rd echelon but also able to provide additional subspecialty care. More-extensive ophthalmic surgical procedures to save the globe will be performed at the 4th echelon, where a microsurgical augmentation set and an operating microscope will be located so as to permit vitreoretinal surgery. Required are all diagnostic and therapeutic instruments needed to manage definitively all forms of ophthalmic injury, including IOFB, retinal detachment, and intraocular hemorrhage (including that from laser injury).

Vitreoretinal surgery will generally be performed between 0 and 14 days following an injury; otherwise, fibrous proliferation increases ocular morbidity. Patients requiring vitreoretinal surgery include all those suffering from penetrating eye injuries of the ciliary body and the posterior segment of the eyeball (sclera, choroid, retina). These patients fall into two categories:

1. those without major posterior segment disruption (ie, no major retinal, choroidal, or optic nerve damage) who, after vitrectomy and intraocular lens implant (if necessary), can return to duty within 30 days; one posterior and one anterior chamber–style intraocular lens must be available at this echelon of care; and
2. those whose posterior segments have been significantly disrupted and will require evacuation to CONUS after vitrectomy.

A patient with an IOFB is not to undergo magnetic resonance imaging (MRI) until the FB is shown not to be magnetic (eg, by the magnet-ultrasound test).

Intraorbital, but extraocular, FBs will be left in place unless they are (*a*)large enough to produce a disturbance of eye or optic nerve function, (*b*) composed of vegetable matter or wood, or (*c*) infected. Orbital fractures will be repaired if clinically indicated; few pure blowout fractures of the orbital floor will require surgery.

At the 4th echelon, three ophthalmologists are required: one with vitreoretinal subspecialty expertise, one with anterior segment expertise, and one with ocular plastic and adnexa subspecialty expertise. The ophthalmologists should be supported by five corpsmen trained to assist in the care of ophthalmic patients in the clinic and in surgery. The clinic should be large enough and so equipped that two ophthalmologists can work simultaneously.

It must be kept in mind that surgical ophthalmic patients require evaluation in an outpatient clinic (an "eye lane") before they are returned to duty, and that the ophthalmologists in theater will have many ophthalmic patients (eg, those suffering from infections and inflammations) who require medical care.

One optometrist should be assigned to each 3rd- and 4th-echelon hospital where ophthalmologists are assigned. The optometrist will perform refractions and supervise the optical shop for the region; he or she should be co-located with the ophthalmologists to speed patient care and thereby increase return-to-duty rates.

The benefit of expertly performed ophthalmic surgery at the 3rd and 4th echelons can be totally undone by poor or no care of the eye casualty during aeromedical evacuation to CONUS. The theater Army ophthalmologist must work closely with his or her Air Force counterpart to ensure adequate in-flight care of the eye casualty.

All utilizable ophthalmologists must be identified with a military occupation specialty (MOS) that specifies whether or not the ophthalmologist is a subspecialty expert (eg, 60S9B0, general ophthalmologist; 60S9B1, anterior segment subspecialist; 60S9B2, vitreoretinal expertise). Military ophthalmologists must be prepared, especially if their hospital provides area support, to treat members of allied forces and indigenous peoples—the latter group necessitating an awareness of relevant geographical ophthalmology (eg, the diagnosis and treatment of endemic trachoma). Hygiene is of even more importance, albeit harder to effect, in the combat zone than in the United States. If contact lenses are worn in the combat zone, significant keratopathy can be expected to occur, possibly leading to the loss of an eye. In outpatient facilities, epidemic keratoconjunctivitis and gonococcal conjunctivitis may be encountered. In the operating room (OR), the use of prophylactic antibiotics should be carefully considered.

The vagaries of military medical supply will ensure that military ophthalmologists will have to improvise at times. The ophthalmologist may need to quickly learn to lead and administer an eye service, supervising perhaps an optometrist and several corpsmen, some of whom will be expected to provide optician services.

OPHTHALMIC CARE IN THE PERSIAN GULF WAR

The eye care provided by ophthalmologists during the Persian Gulf War, both its 6-month defensive buildup phase, Operation Desert Shield, and the short (6-wk) offensive phase, Operation Desert Storm, encompassed a broad range of ophthalmic issues and problems in theater, from the combat support hospital (CSH) to the GH. In future conflicts, ophthalmologists will again be charged with the awesome responsibility of preserving the vision of wounded soldiers and civilians. Unfortunately, there are no all-encompassing answers to many of the problems that arose during the Persian Gulf War. Necessity and individual initiative frequently prompted the only pragmatic solutions. Specific ocular injuries encountered during the Persian Gulf War have been described and analyzed elsewhere.[26,27] For the sake of completeness, I (T. H. M.) will briefly comment on these injuries; however, the thrust of this section will be to describe how the theater evolved over time, what problems arose, how attempts were made to deal with these issues, and what lessons were learned.

During the Persian Gulf War, it was my privilege to serve a dual role as both the Theater Ophthalmology Consultant and Deputy Commander for Clinical Services of the mobile 47th CSH. This combination of duties gave me the opportunity to travel to different parts of the theater and interact with many hospitals, both reserve and active duty. The Persian Gulf War evolved as a war of movement, where many medical units (such as my own) moved frequently to provide medical care to a huge army, which moved in a generally northerly direction. The medical mission also gradually shifted as the military strategy changed from the defensive posture of Operation Desert Shield to the offensive one of Operation Desert Storm. In an attempt to convey the changing nature of the medical mission, I will occasionally describe the status of my own unit as the military situation matured and go beyond the scope of a pure ophthalmic discussion. Ophthalmology did not exist in a vacuum during the Persian Gulf War, and any discussion of ophthalmic care must, of necessity, encompass nonophthalmic issues.

Following the invasion of Kuwait in August 1990, the United States responded with the deployment of the 82nd Airborne Division, along with other relatively small Air Force and Navy units. Local Saudi Arabian ophthalmologists provided the initial ophthalmic care for these units. Later, during October and November, as corps-sized combat elements were formed, larger hospitals arrived with surgical subspecialists, including ophthalmologists. The smallest units with ophthalmologists assigned as staff were CSHs. Most of the more than 20 active duty and reserve ophthalmologists in theater throughout operations Desert Shield and Desert Storm were assigned to Army EHs and GHs, as well as to Navy fleet hospitals and hospital ships. Usu-

ally, such hospitals had one ophthalmologist each. There were no Air Force ophthalmologists in theater.

I was a staff ophthalmologist at Madigan Army Medical Center (MAMC), Fort Lewis, Washington, at the time of the invasion of Kuwait. Not long after the invasion, I joined the 47th CSH stationed at Fort Lewis, which had been alerted to go to Saudi Arabia. As with nearly all medical units eventually sent to Saudi Arabia, we were by no means completely ready for deployment. Few, if any, medical units had actually inventoried and used their equipment in the field for real surgical cases. Fortunately, our unit had several weeks to break down and examine our equipment. This was indeed fortunate, because some equipment was found to be missing or inadequate. Given the lack of state-of-the-art equipment, particularly in surgical subspecialties, many surgeons "borrowed" equipment from MAMC. This borrowed equipment was to prove invaluable in the treatment of injured and wounded soldiers. (The use of borrowed equipment was very common in active duty medical units deployed to the theater.)

Equipment and Facilities

Because I frequently use the term "state-of-the-art field equipment," it is appropriate to define this term with respect to ophthalmology. With a severe ocular injury, as is frequently observed in war, prompt definitive surgery is absolutely necessary to preserve vision. It is generally accepted that a corneal/scleral laceration, for example, must be sutured with watertight closure within no more than 12 hours of injury. Simultaneously, an anterior vitrectomy and a lensectomy must frequently be performed. These basic procedures help (*a*) prevent hypotony, bacterial contamination, and massive inflammation, and (*b*) preserve the anatomical integrity of the eye, which will improve the success of later ocular surgery, if it is indicated. Any well-trained ophthalmologist can perform these procedures quickly in any field OR with the aid of an OR microscope and a battery-operated vitrectomy unit. Since the mid 1980s, portable OR microscopes (suitcase-sized) and battery-powered vitrectomy units (briefcase-sized) have been available. They are largely designed for ocular surgery in the Third World and have been used under conditions far more crude than those experienced by most military surgeons in a war zone. Thus, for purposes of this discussion, state-of-the-art ophthalmic equipment is defined as

- a portable operating microscope,
- a battery-powered vitrectomy unit,
- appropriate microsurgical instruments,
- appropriate sutures, and
- ophthalmic medications.

Our unit personnel arrived by commercial air in Dhahran, Saudi Arabia, on 11 October 1990. Our hospital equipment, and that of nearly all hospitals of mobile army surgical hospital- (MASH-) size or larger, was transported by ship. We were quickly taken by bus to "Cement City," a heavily guarded, barbed wire–enclosed camp erected within the confines of an old cement factory. It was composed of row after row of large Arab tents. During this time, nearly all incoming units, medical and otherwise, were temporarily billeted in this facility. Early in the deployment, because of the rapid rate of unit arrival, this encampment was overwhelmed with soldiers, the numbers of whom far exceeded this area's capacity for support. The poor sanitary conditions coupled with extreme heat resulted in many diarrhea and heat casualties; numerous soldiers were hospitalized, including some from our unit.

Many hospitals had similar experiences using the Cement City staging area before they moved west into various desert locations. After leaving Cement City, most MASHs and CSHs were established roughly along a north/south line about 100 miles west of Dhahran. This configuration was necessary to support combat divisions, which were spread out in this general area. The larger EH and fleet hospitals were initially constructed near the coast, with three EHs located around Dhahran and a GH and a Navy fleet hospital located in Bahrain. Later, four EHs were located at King Khaleid Medical Center, and several more were located along an east/west line, roughly along Tapline Road from Rafha to near the Persian Gulf coast. There were 21 EHs in theater, and a GH was located in Riyadh. Also, the Navy hospital ships *Mercy* and *Comfort* were present in the Persian Gulf before, during, and after the Persian Gulf War.

Some of the first hospitals constructed in Saudi Arabia, including my own, used Vietnam-era inflatable MUST (medical unit, self-contained, transportable) equipment (ie, the inflatable subsections were latched together to form hospital wards). If left alone, the inflatable sections would leak air, similar to a leaking car tire; to remain functional, the MUST hospitals needed constant reinflation. The first ophthalmic emergency surgical cases performed during Operation Desert Shield were done uneventfully in MUST OR boxes, which are

about one-third the size of a standard DEPMEDS (*dep*loyable *med*ical *s*ystem) OR.

Numerous problems became apparent during the hospital-construction phase, and these were to plague medical units for months. Proper supplies and equipment, ophthalmic and otherwise, were almost universally lacking in theater when we arrived. Although many ophthalmologists blamed "the Army," the reasons for this oversight were fourfold:

1. Many ophthalmologists simply never took the initiative to examine their equipment prior to deployment. Thus, even though some PROFIS (*pro*fessional *fi*ller *s*ystem) ophthalmologists had been assigned to their hospitals for years, very few had ever performed a hands-on inventory of their equipment.
2. Some ophthalmologists were assigned to units far from their home stations, and for them, equipment inspection was logistically difficult.
3. Some hospital administrators were reluctant to break down equipment for examination by physicians. Many felt that reviewing the equipment list should be enough. However, the equipment list was frequently difficult to interpret and did not necessarily reflect what was actually present.
4. The Table of Organization and Equipment (TO&E) was outdated, and modern equipment and supplies were never part of the plan. This equipment problem was compounded by the fact that many units were undergoing a transition from MUST to DEPMEDS equipment at about the time of the deployment.

For many reasons, therefore, units found themselves without proper equipment. In fact, of more than 20 ophthalmologists in theater, only 1 or 2 at most had operating microscopes on arrival in Saudi Arabia. No vitrectomy units were ever delivered, and very limited supplies of viscoelastics and even basic microsurgery instruments existed in theater.

Thus, the theater MEDSOM (*med*ical *s*upply, *o*ptical and *m*aintenance), which was originally located in Dhahran, was put in the unenviable position of trying to provide medical supplies, ophthalmic and otherwise, to many medical units arriving in theater. Although these dedicated supply personnel did a remarkable job overall, they were never able to supply all medical units with all ophthalmic needs. I might add that the equipment shortfalls were not limited to ophthalmology. For example, some EHs arrived in theater without functioning anesthesia machines, ventilators, proper sutures, and other basic equipment and supplies.

Lack of equipment proved to be an almost insurmountable problem. In late October and early November 1990, it was becoming obvious (for the reasons mentioned above) that surgical units were arriving without even basic ophthalmic equipment. With this in mind, I contacted the Ophthalmology Consultant to the Surgeon General, Colonel Kenyon Kramer, at Walter Reed Army Medical Center, Washington, DC, and we formulated a plan to purchase and ship operating microscopes, slitlamps, and other equipment to Saudi Arabia. Although this equipment acquisition was well coordinated at Walter Reed and the Dhahran MEDSOM, we had no control of the circumstances between these two points, and our plans met with limited success. For example, of the 12 or so operating microscopes purchased and shipped to Saudi Arabia during Operation Desert Shield, I am aware of only 2, including the 1 that I received, that actually arrived at the proper receiving units. Very few of the operating microscopes were ever found—even after the war ended—although numerous attempts were made to track this equipment. Basically, we found that trying to fill such critical gaps in specialty equipment after arriving in theater was hopeless. The result was that ocular casualties were, in general, poorly treated by many hospitals, particularly those nearest where the casualties were generated.

Fortunately, the personnel of one GH and several EHs were actually moved directly into well-equipped, preexisting Saudi Arabian medical centers. Thus, ophthalmologists and other surgical subspecialists from these units inherited relatively high-quality equipment and a modern hospital setting. This arrangement enabled the evacuation system to have several high-quality eye centers in Saudi Arabia, where some severe ocular casualties could be diverted.

At other hospitals, unfortunately, because patients had coexisting wounds that left them unstable for evacuation, ophthalmologists were frequently forced to treat severe ocular injuries with substandard equipment or risk complications as a result of not closing the wounds. For example, suturing corneal lacerations with loupes, inappropriate sutures, and without viscoelastics was commonplace. This resulted in the need for many patients to be resutured on transfer to a hospital with appropri-

ate microsurgical equipment and supplies. There is no question that this lack of proper equipment led to increased ocular morbidity in wounded soldiers. Thus, fewer than a half dozen well-equipped ophthalmologists in Saudi Arabia provided most of the definitive ophthalmic care, which led to some ophthalmologists being overwhelmed with surgical cases.

In addition to equipment needs, ophthalmology supplies such as viscoelastics, silicone tubing, and some antibiotics were difficult to obtain through the overwhelmed medical supply system. Many ophthalmologists found the US mail, coupled with overseas telephone service, to be a viable resupply alternative.

To improve troop morale, the military quickly established civilian-operated satellite telephone banks in Saudi Arabia. These were initially created near the coasts, but by December 1990, divisions in more remote areas also had telephones. This high-priority communication system was of far higher quality than the poor systems used by medical units. In fact, it was easier to contact anyplace in the United States from these telephone banks in Saudi Arabia than to use the military telephones to call an EH that was only 100 miles away. The mail system from the United States was also dependable and well cared for, and it was a major morale booster. Thus, the fastest and most dependable resupply system for small medical items was to call a friend at your parent hospital in the United States and ask him or her to obtain supplies and send them to you via the US mail. This method used two, high-priority, dependable, established systems, and it proved beneficial to physicians and patients; using it and individual initiative could somewhat enhance the supply system.

Frequency and Severity of Eye Injuries

Fortunately, few serious ocular injuries occurred during Operation Desert Shield. Several corneal/scleral lacerations, hyphemas, lid lacerations, and facial fractures were treated, but considering that over half a million troops were present in theater, the number of serious injuries was surprisingly low. I suspect that the no-alcohol policy helped to decrease the incidence of serious accidents, and this was reflected in the low number of ocular injuries. However, corneal abrasions and FBs were extremely common. Several severe sandstorms occurred before Operation Desert Storm, and they produced innumerable soldiers with embedded sand corneal FBs. These injuries were usually painful and incapacitating. Fortunately, several CSHs in the Corps area had slitlamps that were used effectively to remove corneal FBs. This local ability to remove corneal FBs greatly decreased the need for time-consuming medical evacuation to larger hospitals. Frequently, periocular fractures, lid and canalicular lacerations, and corneal/scleral lacerations were also successfully repaired and followed up at CSHs, which greatly lessened the strain on the evacuation system. Finally, contact lens problems related to dust and sand were extremely common early in the deployment, because many soldiers arrived in theater without backup eyeglasses. This situation largely resolved after facilities for making prescription eyeglasses became available in theater.

By the start of the air war in mid January 1991, more than 20 ophthalmologists were in theater. Most were in stationary Army EHs and Navy fleet hospitals, and few had access to state-of-the-art basic ophthalmic field equipment. By various means, however, ophthalmologists were slowly accumulating equipment and supplies that would enable them to provide some form of care to wounded soldiers. Most had acquired slitlamps. The 6 weeks of air war gave ophthalmologists another reprieve in which they cross-leveled equipment and supplies to the best advantage. Although theater ophthalmologists made a concerted effort to share supplies and equipment, the extremely poor theater communication system between hospitals made this difficult.

Simultaneously with the air war, mobile hospitals slowly moved closer to the Iraqi border, roughly in the same area with the divisions they would later support during the ground invasion. For example, by the start of the air war, my unit had moved 150 miles further north and was located about 20 miles south of King Khaleid Medical Center, which was less than 100 miles south of the Iraqi border. During the entire air war, our mobile hospital, as well as most others, was nonfunctional, because all the equipment was packed on trucks in preparation for the invasion of Iraq. Therefore, any serious injury, ocular or otherwise, that occurred during this time was sent directly to the closest EH, bypassing the mobile hospitals. About 3 weeks before the invasion, most mobile hospitals, including my own, moved further north to within about a dozen miles of the Iraqi border. By the time of the invasion, our CSH had been downsized for increased mobility. We went from a 200-bed, partially mobile hospital to a 24- to 30-bed, fully mobile hospital (Figure 2-13). (NOTE: construction of a 200-bed CSH required

Fig. 2-13. Aerial view of the 47th Combat Support Hospital at Division Support Area 3 in Iraq (24th Infantry Division). Such downsized hospitals were used during the Persian Gulf War to increase mobility.

several days, whereas the small, fully mobile version could be functional in < 6 h.) This change was necessary to keep up with divisions that would soon be advancing fast, deep into Iraq. On the day of the invasion, my unit was incorporated into a huge convoy that entered Iraq in support of the 24th Infantry Division.

During the air war, which began 15 January 1991, ocular casualties continued to be light, for the most part. Most ocular injuries were of the variety that we would expect to see with a large number of young troops, and were related to accidents or athletic injuries. There were two exceptions:

1. Not long into the air war, the Iraqis began to launch SCUD missiles into Saudi Arabia. They were poorly aimed and frequently hit by our Patriot missiles, but the SCUDs occasionally landed in or around the troops or other populated areas and caused numerous injuries, ocular and otherwise. SCUD missile alerts were also a disruptive nuisance to all because they forced soldiers to don their cumbersome chemical protective clothing.
2. The second exception was the Iraqi attack into Kafji, Kuwait, just north of the Saudi Arabian border. This led to an Allied response, largely Marine, which resulted in a small number of serious ocular injuries. Thus, the air war provided a few Allied ocular casualties but nothing that stressed the system.

Medical Evacuation

With the onset of Operation Desert Storm, the medical situation changed drastically and exposed the strengths and weaknesses of the medical care system. All hospitals, from forward surgical teams to GHs, had known for weeks of the plan and timing for the invasion of Iraq and Kuwait. The carefully planned medical evacuation system, heavily dependent on helicopter assets, was well understood by all units (Figure 2-14). The basic medical evacuation plan was (1) to provide lifesaving medical and surgical care to wounded patients at mobile hospitals in Iraq and Kuwait, and then (2) to transport the injured quickly by air to larger, better-equipped hospitals in northern Saudi Arabia for more-definitive care. Because of the long distances traveled into Iraq by Allied forces, however, particularly in the western desert, the evacuation chain was longer and considerably more complex in the Iraqi theater, compared with the less-extended evacuation lines of the Kuwaiti theater.

The chief strength of the plan was the evacuation system itself. The air ambulance assets, largely UH-1 and UH-60 aircraft, were dependable and numerous enough to provide excellent and timely patient transport. For ophthalmologists, the chief weakness of the medical system, as previously discussed, was the lack of appropriate equipment to adequately treat serious ocular injuries, largely at the EH level. Thus, although the movement of patients was well planned and supported, the oph-

Fig. 2-14. Map showing hospital positions in Iraq and northern Saudi Arabia at the time of the ceasefire in the Persian Gulf War.

thalmic treatment rendered was, in general, substandard.

Insights From the Persian Gulf War

Although detailed descriptions of ocular and ocular adnexal injuries treated during the Persian Gulf War have previously been published,[26,27] four findings should be emphasized:

- Fragmentation injuries from various munitions accounted for 78% of ocular injuries in Operation Desert Storm (Figure 2-15). This approximate percentage has been remarkably consistent in every major war since World War I. Thus, not surprisingly, corneal/scleral lacerations, IOFBs, retinal injury, and traumatic cataract accounted for two thirds of ocular injuries described during Desert Storm. These data suggest that ocular surgeons must have the surgical skill and equipment to treat such injuries—so they can salvage injured eyes.
- Of the nearly 200 serious ocular injuries reported during Operation Desert Storm, 32% occurred in Iraqi troops. The Iraqi medical evacuation and treatment systems were greatly disrupted during the air war before the ground invasion. Thus, many Iraqis who were wounded in the ground war received little or no care before they were treated by advancing Allied medical personnel. In the mobile hospitals in Iraq and Kuwait, where many Iraqis first received care, it was common to see gangrenous, debris-laden, nearly amputated limbs, which had never received even basic first aid. Although no statistics are available, this delay in treatment of injured Iraqi personnel undoubtedly increased ocular morbidity. The most common injury by far in Iraqi soldiers occurred as a result of blast fragmentation from exploding ordnance of an "unknown" variety. Most Iraqis literally had no idea what hit them.
- Among the battle wounded of any nationality during Operation Desert Storm, isolated ocular injuries were rare. Because most ocular injuries resulted from blast fragmentation, the typical wounded soldier had numerous additional nonocular fragmentation wounds. Patients were rarely anesthetized solely to treat an eye wound. Typically, a patient was delivered by helicopter, quickly evaluated in the emergency room by various surgeons, and then, if necessary, taken to the OR. Once anesthesia was achieved, several surgeons would operate simultaneously on the patient to quickly and efficiently treat all the injuries. During mass casualties, OR time was very valuable; the goal was to treat the patient and rapidly turn the room around for the next casualty. Only rarely was time allotted for extensive, time-consuming surgery of any kind. The main ophthalmic goal in a mass casualty situation was to obtain watertight ocular closure. If time was available during the initial surgical procedure, more-complex surgery such as extensive vitrectomy and lensectomy was accomplished. Frequently, such time-consuming procedures were postponed until appropriate operating time was available.
- The Persian Gulf War also demonstrated the occurrence of ocular injuries caused by plastic landmines (Figure 2-16) as well as lasers. Although their mechanisms of injury differ markedly, plastic landmines and lasers have some elements in common: both are relatively inexpensive to produce and easy to use, and their damage potential and lethality will increase with advances in technology. Although the numbers of these injuries were comparatively small during

Fig. 2-15. Fragmentation wounds in a young soldier. Note that some degree of protection was offered at the time of injury by the patient's flak vest. This is in contrast to the neck and face areas, which received numerous fragmentation wounds.

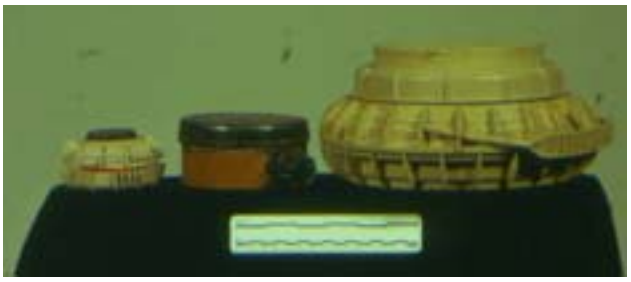

Fig. 2-16. Landmines used by Iraqi forces during the Persian Gulf War. Those on the left and right were made in Italy, and the landmine in the center was manufactured in Russia; all are composed largely of plastic. Reproduced with permission from Mader TH, Aragones JV, Chandler AC, et al. Ocular and ocular adnexal injuries treated by United States military ophthalmologists during Operations Desert Shield and Desert Storm. *Ophthalmology.* 1993;100:1465.

the Persian Gulf War, the potential is huge that such injuries will occur in future conflicts. Unfortunately for the casualties, the localization of plastic FBs and the proper care of laser injuries has been and continues to be problematical.

SUMMARY

Few would contest the proposition that those who stand in the day of battle for us all deserve the best medical care possible. It should, therefore, be the objective of the military ophthalmologist to make the gap between the practice of ophthalmology in the TO and the highest standards in CONUS as small as possible. This is accomplished by

- keeping in mind the principles that underlie such practice in the TO;
- incorporating advances made in civilian ophthalmology into military ophthalmology as soon as possible;
- fighting for the resources required to provide such care;
- educating all who deal with eye-injured casualties;
- putting the best military ophthalmologists in the TO so that they can provide immediate, expert, definitive care to casualties with eye injuries and diseases;
- urging the wearing of eye armor during the conduct of all eye-hazardous activities;
- having a senior ophthalmologist serve as the TO ophthalmology consultant; and
- learning to work with neurosurgeons and head-and-neck surgeons.

The injuries that cannot be prevented should receive the very best care our country is capable of providing, and that care must be provided within the TO. Deferring expert eye care until after the casualty is evacuated from the theater will produce preventable blindness. Denying appropriate eye care to the nontransportable casualty in the TO will do the same.

The Persian Gulf War demonstrated how quickly ocular injuries can be generated in a modern battlefield. The war also exposed the fact that the overall ophthalmic surgical capabilities in theater were suboptimal. It clearly showed the absolute necessity of providing appropriate equipment and training to surgical units during peacetime so that they can be properly prepared for wartime deployment. This conflict may also have given us a preview of new types of ocular injuries to be seen in future wars. Therefore, the Persian Gulf War confirmed the lessons of the past and was perhaps an ominous introduction to the ophthalmic injuries of the future.

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