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Arthur M. Smith

Can We Effectively Control Human Costs during War at Sea?

Captain Arthur M. Smith, MC, U.S. Naval Reserve

DESPITE INCREASINGLY more sophisticated naval weaponry and the greater use of automation in military systems, we remain heavily dependent upon competent human assets to facilitate combat operations. History has repeatedly demonstrated, however, that the human costs of naval warfare can be substantial! The saving of lives in close support of combat can thus contribute significantly to a navy's effectiveness.

Naval warfare is a highly dangerous undertaking in the context of personnel safety. A ship is designed primarily to facilitate its offensive capabilities. The extraction and immediate treatment of casualties must often be subordinated to the continuation of the mission, as well as to salvaging the integrity of the ship's physical structure in the event of fire, structural damage, or imminent sinking. Delays in the immediate delivery of medical care are therefore inherent in this process, and death, as well as deterioration of injuries, is the inevitable outcome—a situation often made more complex when it is necessary to abandon ship, risking hypothermia (exposure), immersion (drowning), and underwater blast injury.

In addressing the fundamental components of casualty care delivery at sea, several axiomata apply:

- The severity of injury that can be effectively treated aboard any ship is generally constrained by the limited medical equipment and health care personnel available. This is heavily influenced by the adequacy of medical outfitting of ships, as well as by the limited level of medical personnel training, especially among the independent duty trained corpsmen who staff the majority of surface ships and submarines.
- The number of injured crewmen that can be treated is also significantly affected by the limited medical spaces available on any given vessel.
- The maximal limits of survivability of the seriously wounded are ultimately influenced by transfer capability, which is determined by the tactical situation as well as the geographic location of the ship relative to other medical resources.

Dr. Smith is a clinical professor of surgery and military medicine at the Uniformed Services University of the Health Sciences in Bethesda, Maryland, and a professor of surgery (urology) at the Medical College of Georgia in Augusta, Georgia.

Unfortunately, operational planning and execution can be impacted adversely by unfounded expectations concerning the capabilities of afloat medical facilities. This is especially true if large accumulations of casualties develop within afloat units which are unprepared to provide adequate care. It is, consequently, in the interest of line commanders to become better informed "consumers" of this important facet of operational support. A realistic appreciation of the intrinsic assets and shortcomings of afloat casualty care facilities should thus become an integral part of any preparation for command at sea.

Ships under Attack

During land-based military campaigns, diseases and non-battle injuries have traditionally exceeded the rates of the wounded in action. This notwithstanding, the greatest burdens placed upon shipboard medical facilities during combat are the logistical requirements and level of expertise needed for treating battle injuries. Understanding the types of injuries generally sustained in naval warfare, as well as recognizing the conditions under which remedial care may be rendered, are an important responsibility of command in terms of both planning and implementation.

A recent analysis of surviving World War II navy casualties showed that penetrating wounds and burns constituted over sixty percent of the battle wounds incurred within ships under attack.[1] Following munitions explosions within the relatively confined spaces of ships, casualty data from naval warfare have generally confirmed a high frequency of penetrating wounds, in multiple sites, emanating from the release of large quantities of shrapnel. In addition, the fires resulting when fuel-laden *kamikaze* aircraft, bombs, and torpedoes were prominently utilized as weapons, and the need to fight these fires immediately even in the face of continuing combat, led to a high frequency of extensive burns, toxic gas inhalation, and asphyxiation among crew members.

The results of weapons-testing as well as extensive field experience continue to demonstrate that when munitions penetrate an armored structure such as a tank or ship, a series of secondary phenomena occur simultaneously:

• As the explosive round or missile penetrates the outer physical structure, the transmission of accelerative forces is converted into both the formation of multiple shrapnel fragments which are then dispersed among crew members, as well as less visible yet formidable blast overpressure waves. The latter have been well-documented as sources of serious disruptions of lung and abdominal tissues among victims of naval warfare, both within ships and when submerged in water, even without overt signs of external body injury.

• Furthermore, there are significant hazards for burn injury from both the ignition of weapons propellants as well as target incineration. There is also the danger of contemporaneous generation of toxic gases. Burning propellant leads to the release of vaporized toxic acids. Carbon monoxide and nitric oxide are also produced, both of which, when inhaled and absorbed by victims, prevent the blood hemoglobin from transporting oxygen to body tissues. When aluminum is penetrated by high-explosive ammunition or by a kinetic energy round, the resultant flaming hot jet "fixes" atmospheric nitrogen, forming high levels of nitrogen dioxide gas (NO_2). The latter is highly soluble in water and when inhaled is absorbed into the respiratory tract where it is converted into nitric acid, a severely caustic irritant to the airway lining. It also penetrates to deep lung tissue where it causes injury to the lung's ability to absorb oxygen and release carbon dioxide. Furthermore, physical exertion following exposure to NO_2 has been shown to increase substantially the degree of lung damage.

• Burning plastics and insulation materials may release such toxic vapors as hydrochloric acid, formaldehyde, and hydrogen cyanide gas, all of which can be inhaled and prove most harmful to personnel.

Additional "navy unique" problems entailing difficulties with "survival at sea" have also been well documented. Following World War II, it was found that almost two-thirds of all fatalities at sea were lives that were lost during the ship abandonment-survival phase of naval combat operations. Of the seventy-one life-raft survivors from the torpedoed Argentine cruiser *General Belgrano* during the Falklands conflict, sixty-nine suffered from hypothermia (exposure), eighteen of whom died from this condition. How many of the three hundred or more deaths actually occurred during the survival phase following abandonment is not known, but it probably accounts for the majority.[2] Following Argentine air attacks upon the HMS *Coventry* and the *Atlantic Conveyor*, when survivors were obliged to take to life rafts or to the water, two *Coventry* crew members drowned, and most of the twelve from *Atlantic Conveyor* who died were in the water and no doubt experienced profound hypothermia. Even crew members in life rafts ultimately required treatment for hypothermia.[3]

Another cause of injury and death among waterborne survivors is the phenomenon of immersion blast exposure. In October 1967, Egyptian missile boats attacked and sank the Israeli destroyer *Eilat* opposite Port Said, Egypt. While the surviving crew members struggled in the water, the Egyptians fired another missile that missed the destroyer and exploded in the water nearby. Of the thirty-two *Eilat* sailors rescued after the explosion, most suffered significant internal abdominal and lung injuries, without any external signs of bruising or injury, and required emergency surgery. These survivors had experienced "immersion blast injury," a phenomenon rarely seen in peacetime but long documented in military medical tradition.[4] In World War I, Royal Navy medical officers reported instances of immersion blast injury among waterborne personnel exposed to exploding mines and depth charges. During World War II, repeated dive-bombing and torpedo attacks on ships often left the majority of a ship's company in the water after a direct hit. On those occasions, where a depth

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charge, mine, or torpedo exploded near swimming survivors, grave danger to life existed from water blast—and death frequently occurred.[5]

The unique conditions under which naval warfare is conducted also have a significant impact upon casualty survival during fleet operations. Several historical anecdotes reflect the difficult problems encountered when rendering casualty care during naval combat:

• The USS *Princeton* (CVL-23), after being struck by an aerial bomb from a *kamikaze*, experienced significant blast and fire damage. Casualties included seven deaths, ninety-two missing, and 191 wounded. Both the forward and midship battle dressing stations were rendered useless; the main battle dressing station in sick bay and the after battle dressing station had to be evacuated. Later that day, the USS *Birmingham* (CL-62) came alongside to render aid in salvage. Shortly thereafter, an explosion from the after section of the *Princeton*, which blew off her stern, swept the *Birmingham* with blast, flame and debris, killing or wounding half of her personnel as well.[6]

• The USS *Morrison*, a radar picket ship in the Pacific theater during World War II, was hit by four *kamikaze* pilots within a ten-minute period and rapidly began sinking. Attempts to establish the main dressing station in a safe area on the ship were futile since no secure locations existed. One corpsman had been killed and another severely wounded. In the face of existing chaos and extensive wounding, each man had to render first aid whenever and wherever he could. Arresting hemorrhage was the sole objective of any aid rendered. During the two hours that the survivors (ninety of whom were injured) spent in the water they were covered by a heavy layer of fuel oil, which further obscured injuries. The medical officer and remaining corpsman swam from group to group, rendering encouragement and what little aid was possible. After eventual rescue by an LCS, the vessel was obligated to divert to another location to receive an additional twenty-five casualties from a nearby LSM which had also been attacked. Delays in application of even the most primitive level of medical care were obviously substantial.[7]

• A *kamikaze* landed on the superstructure of the USS *New Mexico* (BB-40), killing thirty men and wounding 129 others. During the first four days following the explosion, the personnel were under repeated air attack and remained at constant general quarters positions. *It was not possible to evacuate the wounded until thirteen days later.* Serious strain was placed upon the medical personnel who fully manned battle dressing stations by day to provide first aid to additional casualties, leaving definitive care to be administered only at night. The critically wounded were placed in an air-conditioned ward, but many of the seriously wounded, as well as those with emotional disorders, were of necessity placed into poorly ventilated compartments. The repeated gunfire produced a state of profound anxiety among the wounded, and their retention aboard the battleship had an adverse effect upon the morale of the crew.[8]

• Mass casualty at sea is an additional reality. Two armor-piercing bombs penetrated the flight deck of the USS *Franklin* and exploded within the hangar deck. The resulting secondary explosions and fires resulted in 1,000 casualties among the 3,300 crew members, eight hundred of whom died and were buried at sea. Of those who succumbed, 210 were secondary to burn injury, and 133 others died as a result of smoke and gas-induced asphyxiation.[9]

• Following the abandonment of the *Atlantic Conveyor* after being struck by an Exocet missile during the Falklands war, survivors described the full horror of burning decks, cries of trapped victims, and a precipitate rush into the cold icy sea as the ship was abandoned. Furthermore, the formidable task of evacuating casualties from a fifty-foot-high deck down the side of the ship into life rafts below was accomplished with significant difficulty.[10]

Historical Causes of Casualty Production at Sea

Among shipboard battle casualties in World War II, almost 48 percent were either "missing in action" (MIA) or killed outright (KIA). Of the remaining casualties, 49.5 percent were wounded (WIA), and an additional 2.5 percent died of their wounds (DOW) after arriving at a medical facility.[11]

A recent retrospective analysis of afloat navy casualties during World War II revealed differing trends in casualty data relative to the types of ships attacked (Table 1). Overall, destroyers experienced the most casualties in World War II (14,386), with the highest numbers of WIA, DOW, and KIA, while submarines had the greatest frequency of missing in action. (Rates of casualties aboard submarines are notable not only because less than twenty percent of the casualty total were wounded personnel; when targeted by the enemy, submarines were often sunk, with few or no survivors.) Ten classes of ships in World War II experienced KIA rates at least twice as high as WIA, most prominent of which were not only submarines but also oilers.[12]

On a theater level, tactical ship operations in the Europe-Africa-Middle East region during World War II, no doubt reflecting very high levels of sustained intense combat, yielded a wounded-in-action rate that was seventy-six percent higher than in the Pacific, and a KIA rate which was nineteen percent higher. Operations with the highest casualty rates were the Salerno landings, the Sicilian occupation, the invasion of Normandy, and the west coast of Italy operations.[13]

The types of hostile weapons utilized against U.S. Navy forces had a significant impact upon materiel and personnel attrition. Among those ships ultimately sunk in World War II, the principal responsible weapon types were: torpedoes—forty-four percent; mines—twenty-six percent; bombs—twelve percent; gunfire—eleven percent; and *kamikazes*—eight percent. In some ship sinkings, multiple weapons were utilized.[14]

Attacks by torpedoes were significantly more lethal than gunfire, *kamikazes*, and bombs. (During the Falklands conflict, the torpedo attack upon the Argentine cruiser *General Belgrano* by the British submarine HMS *Conquerer*, yielding greater than three hundred dead, provided further evidence of the lethality of this weapon system during naval warfare.) Although relatively few in overall number, multiple-weapon attacks yielded significantly more killed than individual weapon systems alone. In eighteen of twenty-eight World War II attack incidents where multiple weapons were utilized, however, torpedoes were one of the several weapons used. The higher incidence of mortality among torpedo and multiple-weapon attacks is no doubt related to the fact that they were more likely to cause the sinking of a ship than were bombs, gunfire, or *kamikazes*.[15]

Given the relatively great number of *kamikaze* attacks during the World War II Pacific campaign (190 out of 513 incidents of U.S. ships attacked), they were noted to be responsible for fifty-one percent of injuries among survivors. Predominant casualties following *kamikaze* attacks were penetrating wounds and burns. The number of burns, for example, was significantly greater following *kamikaze* incidents than any other form of weapon utilized. *Kamikazes* were responsible for almost seventy-one percent of navy burn injuries.[16]

Gunfire produced mostly penetrating wounds, and bombs yielded high percentages of penetrating wounds and burns. Among the survivors from torpedo attacks there were many brain concussions noted as well as a general distribution of wounds, attesting to the wound variability associated with blast and over-pressure. As could be expected, attacks utilizing multiple weapons yielded a significantly greater number of wounded than did bombs, gunfire, *kamikaze* aircraft, mines, or torpedoes alone.[17]

The Modern Era of Naval Warfare

Naval warfare has continued to evolve since the era of the *kamikaze* and other relatively unsophisticated, though certainly lethal, weaponry. In this modern age of Exocet and Harpoon missiles and laser-guided munitions launched from aircraft, as well as advanced surface-to-surface missile warfare techniques and sophisticated underwater warfare technology, the potential for death and injury at sea continues.

During the Falklands conflict, the Argentine bombing of the British landing ship *Sir Galahad* resulted in the sudden generation of 179 casualties, including eighty-three burns, many lung problems from acrid smoke inhalation, and a large number of extensive tissue and bone injuries.[18] Elsewhere, a single Argentine missile penetrated the HMS *Sheffield*. Although the warhead failed to explode, the searing heat generated by its passage through the hull and into the forward engine room was sufficient to set fire to paint, plastic cable insulation, and other flammable materials. Within fifteen to twenty seconds the ship was permeated

Table 1
World II Naval Casualty Data by Ship Class

25 Battleships (BB): 22 were attacked on 43 separate occasions—by *kamikaze* aircraft in 16; by gunfire on 14; bombs in 4; torpedoes in 6; and by multiple armaments in 3. Casualties sustained were 1,684 WIA, 2,061 KIA, and 12 MIA.

25 Heavy Cruisers (CA): 17 were attacked on 32 separate occasions—by *kamikaze* in 5; gunfire in 10; bombs in 4; torpedoes in 9; and by multiple armaments in 4. Casualties sustained were 1,804 WIA, 1,484 KIA, and 1,586 MIA.

22 Aircraft Carriers (CV): 16 were attacked on 39 separate occasions—by *kamikaze* in 16; gunfire in 2; bombs in 13; torpedoes in 5; and by multiple armaments in 3. Casualties sustained were 2,603 WIA, 1,885 KIA, and 266 MIA.

417 Destroyers (DD): 206 were attacked on 283 separate occasions—by *kamikaze* in 100; gunfire in 78; bombs in 46; torpedoes in 28; mines in 15; and by multiple armaments in 11. Casualties sustained were 6,895 WIA, 3,565 KIA, and 3,500 MIA.

235 Submarines (SS): The number of attacks is not recorded, but casualties sustained were 1,178 WIA, 444 KIA, and 4,501 MIA.

Source: See 1 and 12 in Notes.

with black, acrid smoke. Twenty died in this incident, and twenty-four additional wounded suffered from burns and smoke inhalation.[19]

Subsequent to the *Sheffield* incident, missile-induced losses in the British fleet from Exocet missiles penetrating the hulls of the *Atlantic Conveyor* and the *Glamorgan* were also substantial. Bombing created additional substantial losses aboard the *Ardent*, *Antelope*, *Coventry* and *Sir Tristam*.[20] Indeed, during the Falklands campaign injury from fire drove the overall proportion of burn casualties to thirty-four percent of all naval injuries.[21] Our own painful experience with casualty generation aboard the USS *Stark* demonstrated that thirteen of the thirty-seven fatalities were due to burns, with six from smoke inhalation and asphyxia, and seventeen deaths from blast injury.[22]

The operational navy environment is a dangerous one even in the absence of direct attack. For example, three major U.S. aircraft carrier fires occurred between 1964 and 1973, leading to forty-four deaths aboard the *Oriskany*, 134 deaths and 162 injured aboard the *Forrestal*, and twenty-seven deaths aboard the *Enterprise*.[23] Subsequent conflagrations aboard the *Belknap*, *White Plains*, *Inchon* and *Bonefish* attest to the ever present potential for death and injury from burns and smoke injury at sea.

Predictions for the Future

Unfortunately, with the advent of new structural materials, fuels, and compartmentalization requirements in navy ships, new fire scenarios must inevitably emerge. In recent years, "advanced materials" (graphite composites, synthetic lubricants, artificial fibers and fabrics, adhesives, matrix systems, and advanced coatings) have played increasingly important roles in military designs. The shipbuilding industry is turning to these materials for use in bulkheads, joiner doors, and even hull components and fittings. Unfortunately, many possess significant thermal and flammability properties, as well as the propensity to form many toxic by-products upon incineration. Furthermore, fire-effect studies on the integrity of bulkheads separating ship compartments have demonstrared the easy propagation of these particulate by-products of combustion, as well as smoke, through the various conduit systems and wire bundles which penetrate these barriers.

Fire problems on ships also vary in accordance with the design and function of these vessels. Whether battle-related or accidental, damage is likely to be more severe if the fire occurs in an enclosed space designed to encapsulate defensively personnel and equipment. This is especially true in such high risk enclosures as submarines. Aboard some newly designed surface ships as well, the trend in ventilation design is also toward closed loop systems. This will make surface ships' fire problems more akin to submarines, with greater concern over toxic gas dissemination.

Utilizing the predictive data within the navy's "Afloat Manpower Casualty Assessment Model," for example, with due regard for modern armament capabilities and ship design, it has been estimated that a single missile hit aboard a *Perry*-class FFG would result in between forty-six and seventy-six wounded, with death rates varying between thirty-four and 204 depending upon the number of additional missile hits and the degree of damage sustained. (This is at some variance with the number of casualties experienced aboard the USS *Stark* following two missile hits, but casualties would probably have been substantially higher if the ship had had to be abandoned, especially in cold North Atlantic waters.) A CV hit by a series of torpedoes and missiles could expect wounded numbering as many as 1,700, accompanied by the deaths of 2,670 fellow crew members. An AOE attacked with missiles and a torpedo could anticipate 250 wounded and 180 dead. A CG would sustain 167 wounded and 141 deaths under similar circumstances. A DDG struck by two missiles and a torpedo could incur as many wounded as 160, as well as 90 dead.[24] (The nature of casualty estimate models will obviously vary, but the fundamental reality remains that single ships in wartime can be subjected to enormous casualty generation.)

Logistical Support Capabilities Must Match Operational Needs

As the recent Persian Gulf crisis demonstrated, the potential for employment of military forces will probably continue its shift from superpower confrontation to involvement and intervention in Third World regional conflicts. Because of their suitability for dealing with regional crises, mobile and "flexible" joint power projection capabilities will no doubt achieve greater significance in the future. Particular emphasis will be placed upon ready surge forces, especially from maritime assets. As a result of these changes, traditional naval deployments as we now know them will be undertaken only to the extent that they are required for regional deterrence and stability. Regional crisis missions and "situational presence" will achieve primacy. "Forward deployable" rather than "forward deployed" will become the focus of our maritime strategy.

As a result of these strategic changes, there will be increased pressure for self-sufficiency and sustainability of forward deployed forces. Unfortunately, as military access to overseas bases such as those at Subic Bay becomes more restricted, freedom of navigation may be contested more frequently, and overflight rights may be increasingly denied as well. The potential availability of long-term logistical support for our forces at sea, including traditional means for medical support, may thus diminish.

Rethinking Medical Support Capabilities at Sea

Medical services, like other forms of logistical support of military operations, must always adjust to changes in tactics and weaponry. Theater medical support systems must similarly accommodate broad changes in strategy. Fleet medical authorities are consequently obligated to scrutinize carefully changes in the nature of naval warfare, and respond accordingly. Since survival from injuries can be heavily influenced by the application of early resuscitative measures to injured personnel, command examination of medical capabilities within fleet resources is obviously imperative prior to any deployment.

Gradations of medical sophistication have always existed within the varied fleet operational units. In World War II a wide range of ships was critical for implementing successful naval operations and engagements. There were 5,780 navy vessels involved, encompassing 117 different types of ships (Table 2).[25]

Many APAs (attack transports) and a specially designated group of medical LSTs (LST[H]) were augmented by medical/surgical teams. Many major combatants participating in afloat operations (Table 3) were also augmented by medical personnel in addition to medical supplies of varying levels of sophistication. Unfortunately, most other ships carried meagre and very basic medical assets, if any.

Some fleet operational engagements during World War II actually required the use of greater than 1,000 vessels (Table 4). The use of hospital ships (AH) and medical transports (APH) was especially noticeable during several major invasions.[26] During the invasion of Okinawa, for example, the *kamikaze* attacks upon the Fifth Fleet created such intense volumes of casualties among the forces afloat that in order to facilitate the continuity of naval operations, six hospital ships and transports were required for evacuating the mounting shipboard casualties to navy fleet hospitals in Guam.

As proved true in the logistical support of Desert Shield/Storm, fast sealift and shipborne pre-positioned material will no doubt receive greater attention in support of our new world-wide strategy. Since casualties are the inevitable result of any conflict environment, will our medical resources prove equally adaptable to the changes required? Excluding our two current TAH hospital ships, whose immediate future is indeterminate due to fiscal concerns, where are available medical resources in the contemporary afloat navy?

In addition to the limited facilities organic to each specific ship class, more capable medical facilities are often located within the surface battle group or amphibious task force grouping. During war, however, the modern CV will generally be heavily involved in offensive operations and could hardly afford to stand by for sustained reception of large numbers of casualties via sea or air lift. Advanced medical facilities are also located within the ships of the amphibious task force. Although theoretically capable of assuming responsibility for large amounts of casualty care, amphibious medical assets remain relatively untested, other than the aging LPH units that supported U.S. combat operations in Grenada and Lebanon. Their own history does not provide an overly sanguine prognosis.

As noted by a medical officer aboard the principal casualty recovery ship off the coast of Grenada during the "Urgent Fury" operation in 1983: "We were overwhelmed, and the word was not out that we were. It was almost as if the casualties were obliged to 'take a number' and wait their turn to be seen."[27] Indeed, on the first day of the operation, thirty-seven casualties were admitted aboard the USS *Guam*. The blood bank of fifty units of blood on the *Guam* was inadequate, and during the course of the conflict the entire inventory of blood was replaced three times via crew donors.[28] The medical officer continued, "At one point things got so desperate that I merely matched the blood types from dog tags, and drew blood from one donor and immediately transfused it, warm, into one of our patients."[29]

Off the coast of Beirut in October 1983, the USS *Iwo Jima* served primarily as a staging point for subsequent evacuation of a large proportion of the living casualties following the battalion landing team headquarters bombing. Indeed, sixty-one stretcher patients were received within one and a half hours. The after-action report revealed a series of continuing medical equipment malfunctions during the deployment.[30] Fortunately, many of the seriously injured had been sorted out by triage teams on site, and were transported to other facilities. In addition, the activated MEDEVAC system facilitated transfer of most of the stabilized evacuees from the *Iwo Jima* within the day.[31]

Why the concerns? Modern burn management research, for example, pioneered by the army's Institute for Surgical Research at Fort Sam Houston,

Table 2
Most Prevalent Navy Afloat Assets in World War II

LCT	(Landing Craft-Tank)—818
LST	(Tank Landing Ship)—759
LCI	(Landing Craft-Infantry)—617
DD	(Destroyer)—417
YMS	(Auxiliary Motor Minesweeper)—272
LSM	(Medium Landing Ship)—251
DE	(Escort Ship)—243
SS	(Submarine)—235
PT	(Motor Torpedo Boat)—213
APA	(Attack Transport)—176

Source: See 12 in Notes.

Table 3
Major Combatants Participating in World War II Afloat Operations

BB	(Battleship)—25
CA	(Heavy Cruiser)—25
CL	(Light Cruiser)—47
CV	(Aircraft Carrier)—22
CVE	(Escort Aircraft Carrier)—62
CVL	(Light Aircraft Carrier)—9

Source: See 12 in Notes.

Table 4
Hospital Ships and Transports in
Large Scale World War II Fleet Operations

The Okinawa-Gunto operation (3/45-6/45), incorporating 2,343 ships, including 7 AH (Hospital Ships) and 2 APH (Medical Transports).

The Leyte operation (10-12/44)—2,128 ships, including 1 AH and 3 APHs.

The Luzon operation (12/55-1/45)—1,906 ships including 2 APHs.

The Marianas operation (6-8/44)—1,417 ships including 7 AHs and 1 APH.

The Iwo Jima operation (11/44-3/45)—1,183 ships including 3 AHs and 1 APHs.

The Western New Guinea operation (4/44-1/45)—1,041 ships with no AHs or APHs.

Source: See 12 in Notes.

Texas, has conclusively demonstrated that the most common cause of death in burn patients is a combination of inhalation injury and pneumonia. The inhalation injury is the lung's inflammatory response to the inhalation of smoke and other toxic irritants. Its presence significantly increases the death rate among burn patients. When combined with pneumonia, death rates rise an additional sixty percent. To counteract these lung problems, new techniques of machine-assisted breathing are utilized in the early phases of treatment of burn patients with inhalation injury.[32] Modern shipboard medical facilities aboard an LHA generally carry a small number of such machines, known as ventilators or respirators. In 1984 aboard one LHA, the following report was generated in the after-action report of a surgical team following its deployment on the ship: "The ship's central oxygen supply system was inoperable throughout the deployment. According to the ship's medical officer, this condition had existed for several years, necessitating the use of portable cylinder containers of gas in lieu of the 'piped in' system. Calculations, using the number of cylinders in the authorized medical allowance list, reveal that if two patients had been required to have their breathing controlled by a respirator for more than forty-eight hours (unlikely in peacetime, but very possible if battle casualties are taken aboard), the oxygen supply would have been inadequate."[33] In 1989, the same central oxygen supply system remained inoperative!

Limitations within the Fleet

Should fleet commanders realistically equate the capability of our deployed medical personnel and our logistically restricted afloat medical assets aboard, for example, the *Wasp*-class LHD vessels, with land-based facilities? Despite its six operating rooms, seventeen intensive care beds, forty-seven ward beds, and 536-bed overflow capacity, can the *Wasp* be compared with a land-based civilian medical trauma care facility with equivalent numbers of patient care units? In reality, the capabilities and limitations of these land and sea-based facilities are substantially different. Unfortunately, misconceptions concerning the capabilities of afloat medical facilities could ultimately impact adversely upon operational planning and execution.

A comparably sized large urban 300-500 bed hospital which offers services dedicated to the care of trauma victims is extremely resource-dependent and requires an extensive roster of highly trained technicians as well as professional medical and nursing personnel. Twenty-four-hour a day staffing of operating rooms, intensive care units, laboratories, X-ray, and blood bank facilities, as well as essential support services from respiratory therapists and specially trained pharmacists, are critical for insuring survival of the injured patients. They also demand an extensive logistical support network ranging from supply procurement to equipment maintenance. The basic operation of a hospital-based trauma intensive care unit equivalent in size to that found on an LHA or LHD commonly requires the services of one registered nurse per patient, per shift, and an extensive support network required to optimize the opportunities for patient recovery. It is not only exceedingly dependent upon large numbers of highly trained personnel, but may easily generate costs in the millions of dollars per year.

As an example of the significant impact that staff capabilities and availability can have upon the level of services available at a facility dealing with critically ill patients, one should note the experience of the U.S. Navy hospital in Portsmouth, Virginia, in the mid 1980s. Recognizing its diminished ability to support even routine patient care when its nursing resources became limited, it was obligated to announce a reduction in operating bed capacity from 524 beds to 398!

In essence then, no naval ship in a battle mode, except a fully outfitted and staffed hospital ship (AH), can afford to manage completely the dimensions of casualty load to be expected in future naval engagements. "Limited" management would be a more realistic expectation. Even a hospital ship would be heavily taxed if more than a small proportion of the injuries were critical, as evidenced by the logistical and manpower burden generally imposed upon land-based civilian emergency facilities in the face of mass casualty or casualty overload situations.

Recommendations

When considering the delivery of care to the injured at sea, several basic rules of military medical support must inevitably apply. Consistent with the traditional military context of "echelons of care," the casualty must always be moved through a progressively phased health-support system. Each echelon provides a measured increment of care appropriate to the facility available. Only enough care is administered at each point in the medical evacuation process to preserve life and limb, and facilitate the movement of the injured to the next appropriate level. Merely entering wounded personnel into an evacuation chain, without consideration of increments of treatment, may cause undue delay in application of life-saving care. Such delays can also perpetuate the deterioration of relatively simple wounds into complex infected ones, caused by uninhibited growth of those bacteria which commonly contaminate war wounds. The integrity of each echelon is of critical importance.

• First aid, self and buddy care, as well as techniques for survival during and after ship abandonment at sea are most critical and of the highest priority. Without them, it will be impossible for many casualties to survive the journey to the nearest medical support site. This should be supplemented, when possible, by effective and early on-site medical care by independent duty trained hospital

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corpsmen, if available. To render optimally early stabilization of living casualties and initiate proper management of war wounds, specifically trained medical officers or competent independent duty trained corpsmen must be assigned to all combatant vessels, supported by medical stores which reflect combat steaming requirements.

• Early categorization or sorting of the injured (triage) by trained personnel and prioritizing care according to the severity of injury are mandatory. Furthermore, in order to save lives and forestall deterioration of casualties, early surgical removal of devitalized tissue from wounds is required. To strengthen fleet medical needs and implement early wound care, surgical augmentation teams may need to be sent to other ships of the fleet not traditionally augmented by surgical teams, such as logistics ships, repair vessels and tenders, and smaller amphibious ships. This concept entails additional augmentation of existing medical personnel aboard carriers and larger amphibious ships. These teams must be accompanied by sufficient nursing and technical support personnel to facilitate adequate care of large numbers of casualties. An effective blood supply and distribution network must also be emplaced, since wound management is contingent upon an ample forward supply of blood for transfusion.

• Higher level facilities for even more definitive surgery and resuscitation must also be available to fleet casualties. History has demonstrated that the "golden period," the first six hours after injury, is the maximum allowable time limit for achieving beneficial results from treatment of the wounded. To facilitate this, as well as stabilize casualties for eventual long-distance evacuation out of theater, advanced facilities must also be available for intensive definitive surgical care. These are generally located in either afloat facilities (hospital ships) or on land in advanced base logistical support facilities such as mobile or fleet hospitals.

• Recognizing that burns and inhalation injuries are a frequent and serious source of personnel injury, in addition to hypothermia (exposure), immersion (drowning), and underwater blast, shipboard medical treatment protocols must be updated continuously in keeping with current scientific practices in these conditions. Treatment guidelines and professional standards, however, must accommodate the average experience and training level of the health care providers stationed aboard these vessels. Special emphasis must be placed upon those treatment adaptations required within the space and logistical constraints imposed by the shipboard environment. On the other hand, when logistical needs are identified, they must be supported and maintained. This includes training to proficiency on all deployed medical equipment for both operators and repair personnel. Frequent proficiency monitoring by external reviewers should be likewise mandatory.

• Seaworthiness of all medical instrumentation must be determined prior to placement aboard ships, and a supply of appropriate spare parts must accompany all installed medical equipment and be assiduously maintained.

• All potential escape-extraction routes for injured crew members must be identified, especially from engineering spaces. Liberal installation of portable medical supply lockers must be accomplished along all potential escape routes.

Given the dangerous nature of naval combat in the intrinsically precarious environment of the sea, deaths from fire, suffocation, penetrating wounds, blasts, drowning, and exposure are inevitable. The difficulties of entering casualties into a phase-echeloned medical care system in this setting are likewise formidable. Therefore, both the line and the medical community must always seek ways to do better in this critical task.

Notes

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Ψ

I am tired and sick of war. Its glory is all moonshine. It is only those who have neither fired a shot nor heard the shrieks and groans of the wounded who cry aloud for blood, more vengeance, more desolation. War is hell.

Gen. William T. Sherman

Foresight

Why should we build our navy up to the London Treaty limits when it will have nothing to do after we build it. . . . No wars are on now and no war is in sight.

-Congressman Will Wood, 1931