Medical rescue of naval combat: challenges and future
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Abstract
There has been no large-scale naval combat in the last 30 years. With the rapid development of battleships, weapons manufacturing and electronic technology, naval combat will present some new characteristics. Additionally, naval combat is facing unprecedented challenges. In this paper, we discuss the topic of medical rescue at sea: what challenges we face and what we could do. The contents discussed in this paper contain battlefield self-aid buddy care, clinical skills, organized health services, medical training and future medical research programs. We also discuss the characteristics of modern naval combat, medical rescue challenges, medical treatment highlights and future developments of medical rescue at sea.

Keywords: Naval combat, Medical rescue challenges, Rescue highlights, Future development

Background
There is no doubt that Spratly Islands and Diaoyu Islands belong to China. Some countries have disputed over the territory for centuries, and recent increased tension has made the area a substantial issue in Asia. Based on this issue, the possibility of military conflict or naval combat is a problem for the involved countries. In naval combat history, the latest large-scale naval battle was the 1982 Falklands Battle between UK and Argentina, which caused a total of 907 deaths and 1843 injuries [1]. Based on Chinese records of naval combat in 1974 and 1988 between China and Vietnam in the South China Sea [2–4], the weapons used in these limited-scale combats included short-range artillery, guns and grenades. Despite the rapid development of battleships, weapons manufacturing and electronic technology in the last 30 years, naval combat will present many new characteristics.

Established in 1871, U.S. Navy Medicine Health Care now consists of five distinct “Corps”: Medical Service Corps, Nurse Corps, Medical Corps, Dental Corps and Hospital Corps. Each corps consists of personnel specializing in a particular health care field [5]. Additionally, the U.S. has established navy medicine departments around the global to support the Navy and Marine Corps. In Asia, U.S. navy medicine centers exist in Japan, Cambodia, Singapore and Vietnam. These factors indicate the importance of medical rescue at sea [6].

Challenges of medical rescue at sea

Environmental
The battlefield tends to be in the ocean, far from land or shoreline. Casualty rescue would be extremely difficult during the sustained fighting environment in the battlefield. Some characteristics of the seawater include cold temperature, hypertonicity and pathogenic bacteria, which cause additional damage to the casualty [7–9]. For example, compared with simple firearm wounds, the healing time of firearm wounds after seawater immersion can be delayed [10].

Weapons
Widespread use of high-speed and precision-guided underwater explosive weapons or missiles can cause more complex and multiple forms of injuries [11]. Blast damage is the leading cause of death on the modern battlefield, especially in navy combat [12]. For tactical purposes, non-explosive weapons such as infrasound weapons, laser weapons, electromagnetic weapons and microwave weapons can be used on the battlefield.
Combatant distribution
For the purpose of mobility, concealment and ammuni-
tion load, surface ships and marines’ cabins are usually
designed to be narrow and small [13]. Because of the
densely distributed combatants in the cabins, there
could be substantial casualties once attacked. Addition-
ally, the casualties in various cabins would present vari-
dious types of trauma.

Difficulties of medical rescue at sea
Casualty distribution
Combatants in surface battleships and submarines are
concentrated and dense. Once attacked, there would be
substantial casualties at the same time, and the doctors
would have difficulty evaluating all casualties in a short
period of time. In some situations, once combatants are
dropped in the seawater, an unpredictable distribution of
combatants would occur because of the waves and the
battlefield’s blasts. In this type of dispersed distribution,
it is very difficult to search or salvage the casualty,
thereby delaying treatment. The Health Department of
People’s Liberation Army (PLA) invented an electronic
casualty location system that can help search for casual-
ities on land, but it has not been well tested in the naval
setting [14, 15].

Complex injuries
The blast of explosive weapons can cause injuries to
multiple sites of the body at the same time, such as head
trauma, extremity fractures, spine injury and chest or
abdomen trauma. The initial injury mechanism is accel-
eration damage from the blast, and the consequent in-
jury mechanism is deceleration damage from hitting the
bulkhead or instruments inside the cabins [16]. Some
weapons will cause combined injuries such as blast in-
jury, burn injury, seawater immersion injury and decom-
pression injury, etc. [17]. These combined injuries cause
extremely complex clinical manifestations and are diffi-
cult to treat.

Diagnostic and transport difficulties
Well-equipped hospital ships, such as PLA NO.866 hos-
pital ship and USNS Mercy, usually maintain a particular
distance from the battlefield [18]. Sometimes, doctors on
the battleships diagnose the casualty at the place where
the damage occurred by simple medical equipment or
even only by clinical symptoms [19, 20]. Casualty trans-
port from surface battleships to hospital ships mainly de-
dpends on suspended transporters on rescue ships or
limited helicopters [21]. Submarines rarely use surface
transport due to their undercover and combat mission
requirements. Therefore, we must recognize that casu-
ality transport from battleships to hospital ships or
land-based hospitals are very difficult during war [22].

Medical rescue highlights
Self-Aid Buddy Care (SABC)
SABC encompasses basic life support and limb-saving
techniques to help casualty or injured personnel survive
in medical emergencies until medical help is available.
Generally, SABC requires that injury judgments must
be accurate, measures must be quick and everyone
must do their best to make the casualty stable [23]. The
airway, breathing, circulation, disability and exposure
(ABCDE) approach still plays a classic and practical
role in the immediate assessment and treatment of the
critical casualty [24].

Damage control
In the pre-hospital treatment of a critical casualty, the
best method is damage control surgery to avoid further
deterioration [25]. Doctors correct hypothermia, acid-
osis, coagulopathy and other fatal failures at the same
time of initial resuscitation [26]. In encountering mul-
tiple associated injuries, priority attention should be
given to high mortality situations such as shock, bleed-
ing and brain trauma [27, 28]. In U.S. military medicine,
the Forward Surgical Team (FST) has been tested to be
a very efficient group of doctors who can complete dam-
age control surgery independently [29–31].

Efficient transport
For those urgent or critical casualties who need further
medical treatment, it is important to arrange air trans-
port as soon as possible. Forward doctors report the pa-
tient’s information to the higher-level hospital before
transportation so doctors can prepare efficiently to en-
sure the continuous treatment after transportation [32].
Various vehicles (military ships, military planes or civil-
ian ships) should be used to rescue as many lives as pos-
sible during war.

Medical rescue: future tasks
SABC training
The training of all combatants is critical for meeting our
current requirements and preparing for challenges. The
topics of SABC training encompass administrative over-
view, anatomy and physiology, communicable diseases/
universal precautions, airway management, recognition and
control of bleeding, shock management, dressings, banda-
ging, fractures, splinting, heat/cold related injuries, burn in-
juries, victim assessment and patient transportation/litter
movement [33, 34].

Trauma protection and new weapons research
Protection is important for all types of trauma [35, 36].
To relieve blast shock in naval combat, it is necessary to
set anti-shock devices such as anti-shock chairs and seat
belts in the possible positions in the cabins of battleships.
Combination of military and civilian medical forces

It would be efficient to establish a medicine command center that can organize military and civilian medical forces during war. Closer to battle, Forward Surgical Teams (FSTs) could play a substantial role [30]. New diagnostic equipment could be invented, such as portable intracranial hematoma diagnostic equipment and portable electronic monitor devices. To be closer to casualties, there should be enough Dock Hospital or Combat Support Hospitals (CSH) on nearby coasts. Additionally, civilian medical forces also undertake important tasks in casualty care, blood supply, drug supply, etc.

Injury mechanism of seawater

Characteristics of seawater injuries include drowning, cold temperature, hypotonicity and pathogenic bacteria. A study found 21 forms of bacteria from 85 strains in the Nansha district [38]. The average bacterial number was 336.60 ± 160.79 cfu/ml. These bacteria were all highly susceptible to 16 antibiotics. Another study found 34 types of bacteria in the Southeast littoral [39]. The susceptibilities of the bacteria to 21 antibiotics were tested. These investigations are important for the prevention and therapy of bacterial infections related to seawater. It is essential to create a practical rewarming plan for hypothermia in casualties salvaged from seawater [40, 41].

Conclusion

Medical rescue is a complicated and challenging topic. The topic involves many indispensable aspects that should be considered during peace times. We must clearly understand the challenges we face and the weaknesses in our current medical system. Future work should include training and research. The future development of trauma prevention and portable equipment used in medical rescue at sea must be powerful enough to save more people.

Abbreviations

SABC: Self-aid buddy care; ABCDE: Airway, breathing, circulation, disability and exposure; FST: Forward surgical team; CSH: Combat support hospital.

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

Prof. HLJ outlined this paper. Prof. FXB gave many suggestions and summarized some medical rescue highlights. Dr. JH wrote the paper with input from all authors. All authors read and approved the final manuscript.

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