Water search and rescue (SAR) for ship accidents in China: analysis of 12 years' data

Jie Huang[1#], Ning Han[2#], Bi-Qing Jiang[3^], Yan Cao[1], Xiao-Tong Han[1]

[1]Department of Emergency, Hunan Provincial People's Hospital/The First Affiliated Hospital of Hunan Normal University, Changsha, China; [2]Department of Emergency Traumatology, Shanghai East Hospital, Tongji University School of Medicine, Shanghai, China; [3]Medical Affairs Department, Hunan Provincial People's Hospital/The First Affiliated Hospital of Hunan Normal University, Changsha, China

Contributions: (I) Conception and design: XT Han, J Huang; (II) Administrative support: J Huang, N Han; (III) Provision of study materials or patients: J Huang, XT Han, N Han; (IV) Collection and assembly of data: BQ Jiang, Y Cao; (V) Data analysis and interpretation: BQ Jiang, Y Cao; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Xiao-Tong Han. Department of Emergency, Hunan Provincial People's Hospital/The First Affiliated Hospital of Hunan Normal University, Changsha, China. Email: 22623588@qq.com.

Background: Maritime search and rescue (SAR) remains a great global challenge because of the long distances, harsh environment and complicated trauma. A systematic investigation and analysis of China Maritime Search and Rescue Center (CMSRC) data has been lacking. This study aimed to provide more insightful information for future development of a better maritime and aquatic SAR system in China.

Methods: This retrospective study retrieved and analyzed data on the water traffic volume from The Ministry of Transportation, People's Republic of China website and SAR data on ship accidents between January 1, 2008 and December 31, 2019. Spearman's correlation test was performed to analyze the data for the number of ship accidents, number of persons in distress, number of rescued persons, SAR success rate, and SAR forces. The χ^2 test was used to assess significant changes in the proportion of ship accident locations, categories, dispatched SAR forces, and location of deaths annually. The Cox Stuart test was applied to determine the trends in the data from 2008 to 2019.

Results: Between 2008 and 2019, a total of 24,013 ship accidents were reported and recorded by the CMSRC surveillance system; 209,948 persons in distress because of ship accidents were reported; 8,051 individual deaths from ship accidents. Water traffic volume and ship carrying capacity increased while the annual number of persons in distress, ship collisions, and ship collision-related deaths decreased. The SAR success rate (96.17%±0.92%) did not improve despite an increase in the number of rescue ships dispatched during this period. Helicopters (92.40±20.58 min) arrived faster than rescue ships (283.75±40.96 min) but the dispatched number of helicopters did not increase during this period. The average arrival time of nearby passing ships (41.90±7.98 min) was the shortest.

Conclusions: CMSRC efforts mitigated the growth of ship accidents despite increasing traffic volume. More dispatched rescue ships did not improve the SAR success rate without saving arrival time. Future SAR protocols may need to increase and strengthen the role of helicopters and nearby passing ships to improve the SAR success rate.

Keywords: China Maritime Search and Rescue Center (CMSRC); helicopter rescue; persons in distress; ship accidents; water search and rescue

Submitted Aug 29, 2022. Accepted for publication Nov 01, 2022.

doi: 10.21037/atm-22-4530

View this article at: https://dx.doi.org/10.21037/atm-22-4530

^ ORCID: 0000-0002-1718-7671.

Introduction

Merchant sea-shipping is still the most useful international goods transportation method in the world (1,2). To date, there are >80,000 merchant ships used for trading by various merchants internationally (3), and the worldwide shipping fleet is registered in >150 countries or territories with >1 million seafarers (1-4). Reported by World Health Organization (WHO), about 37 million people, around 90% are in Asia, depend on small-scale fishing which is considered highly susceptible to drowning for their livelihoods (5).

The WHO reported that "drowning is the 3rd leading killer of unintentional injury death worldwide". Drowning estimated 236,000 annual drowning deaths globally in 2019, a part of which caused by maritime and aquatic accident (5,6). The sea-shipping business is the foundation of economic globalization, but seafaring is one of the most dangerous professions in terms of occupational health risk because numerous circumstances, such as collisions, grounding, fire and explosions, sinking and other factors, can cause ship accidents at sea, leading to injury or death (4,7,8). A previous study from the United Kingdom (UK) of merchant shipping between 2003 and 2012 showed that the fatal accident rate was 21-fold higher than that of the general workforce (7). Another UK study revealed that there were 17,386 deaths from ship accidents, of which 6,074 were from ship disasters and 11,312 from personal accidents between 1919 and 2005 (9). At the same time, low- and middle-income countries have lower maritime and aquatic search and rescue capabilities (5), which causes that maritime and aquatic accident-caused death becomes a globally public health problem. Thus, it is essential to establish and improve maritime and aquatic maritime search and rescue (SAR) systems in order to reduce the loss of life in seafaring (10-12).

Maritime and aquatic SAR operations frequently, if not always, involve a long distance to the accident site in harsh environments (high wind, rough water, and dark sky) with complicated wounds or dying individuals (12-15). Thus, timely SAR responses to rescue victims at sea could be beneficial, with appropriate resuscitation at the scene followed by prompt and rapid transportation to a medical facility, which would save lives and reduce injury (12-15). In China, there were 1,716,866 registered crewmembers by the end of 2020 and over 152.9 million water passengers in 2021, while water traffic is still growing and ranks the number one in the world (16,17). China Maritime Search and Rescue Center (CMSRC) is part of China's Ministry of Transport. It is responsible for organizing, coordinating and directing major emergencies on highways and waterways in China (17). Such a huge fleet and operation has resulted in a total of 201,897 persons in distress and 24,013 SAR operations between 2008 and 2019 according to the statistics from CMSRC. Nevertheless, a systematic investigation and analysis of the CMSRC data has been lacking and such a study could facilitate and improve the future planning and execution of maritime and aquatic SAR, save more lives, and reduce material loss at sea.

This study aimed to provide more insightful information for future development of a better maritime and aquatic SAR system in China, as well as provide data for the Chinese government to implement more SAR sites along the country's approximately 18,000-km shoreline. We present the following article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-4530/rc).

Methods

Study design and data sources

In this retrospective study, we analyzed the data on maritime and aquatic operations in China by retrieving data from The Ministry of Transportation, People's Republic of China website (http://www.mot.gov.cn/shuju/) and SAR data on ship accidents from the CMSRC website between January 1, 2008 to December 31, 2019. We retrieved and statistically analyzed data on the annual water passenger volume, annual water freight volume, annual number of transportation ships, annual total ship carrying capacity, annual number of persons in distress, annual number of ship accidents, SAR success rate, and dispatched SAR forces. We then compared the composition of annual dispatched SAR forces and the location of death distribution. This study was approved by the Health Research Ethics Committee of the Shanghai East Hospital of Tongji University. The requirement for individual consent was waived by the committee. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Data retrieval and categories

The data on annual water traffic between January 1, 2008 and December 31, 2019 were retrieved from http://www.mot.gov.cn/shuju/, including water passenger volume, water

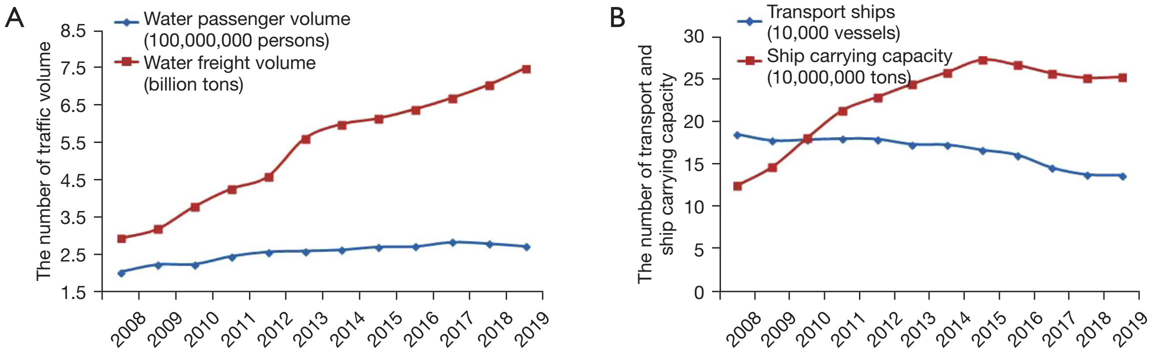

Figure 1 Rapid growth of water traffic volume and ship carrying capacity in China between 2008 and 2019. (A) Water freight volume and water passenger volume. The water freight volume per annum showed rapid and continuous increase and the water passenger volume per annum also increased. (B) Ship carrying capacity and number of ships. The ship carrying capacity showed a rapid increase, associated with a decrease in the number of transport ships per annum.

freight volume, the number of transport ships, and the total ship carrying capacity. The annual ship accidents and related SAR data between January 1, 2008 and December 31, 2019 were obtained from the CMSRC website including the number, category and location of ship accidents, the number of persons in distress, rescued persons and deaths, causes of deaths, number of SAR forces, arrival time of SAR forces, SAR success rate, and mortality rate of persons in distress for different categories of ship accidents.

Further, the categories of ship accidents were counted, including the number of collisions, grounding, fire and explosions, wind disasters, and others (18,19). Collision was defined as a structural impact between two ships or one ship and a floating or still object. Grounding indicated any incident that resulted in shipwrecking or stranding, typically on rocks, beaches, and harbor walls, leading to hull breaches, cargo spills, total loss of the vessel, and human casualties in more serious accidents. Fire and explosions referred to incidents resulting from hazardous material, equipment failure, human errors, and other factors that may cause a potential fire and explosion risk to life safety on board. Wind disasters indicated incidents of shipwrecks, mechanical failure, human drowning, or injuries on board caused by typhoons, gusts, storms, etc. Others included crew injuries, and work injuries among fishermen, capsizing or disappearance of fishing vessels, which were usually presumed to have foundered or other causes of damage.

Statistical analysis

The data were collected into Microsoft Excel® version 2007 (Microsoft, Redmond, WA, USA) and statistically analyzed using SPSS 18.0 (vision 22.0, SPSS, Inc., Chicago, IL, USA). Spearman's correlation test was performed to analyze the data for the number of ship accidents, number of persons in distress, number of rescued persons, SAR success rate, and SAR forces. The χ^2 test was used to assess significant changes in the proportion of ship accident locations, categories, dispatched SAR forces, and location of deaths annually. The Cox Stuart test was applied to determine the trends in the data from 2008 to 2019. Two-side $P<0.05$ was considered statistically significant.

Results

Increase in water traffic volume and ship carrying capacity between 2008 and 2019

Between 2008 and 2019, there was a significant growth in the water traffic volume (*Figure 1A*). The water passenger traffic also increased from 203.30 million people in 2008 to 272.66 million people in 2019, and the water freight traffic increased from 2.95 billion tonnes in 2008 to 7.47 billion tonnes in 2019. In contrast, there was a decrease in the number of water transport ships between 2008 and 2019, but an increase in the average ship carrying capacity (*Figure 1B*).

Change in locations and causes of annual ship accidents between 2008 and 2019

Between 2008 and 2019, a total of 24,013 ship accidents were reported and recorded by the CMSRC surveillance system, of which 74.23% were pure marine accidents, 19.26% were

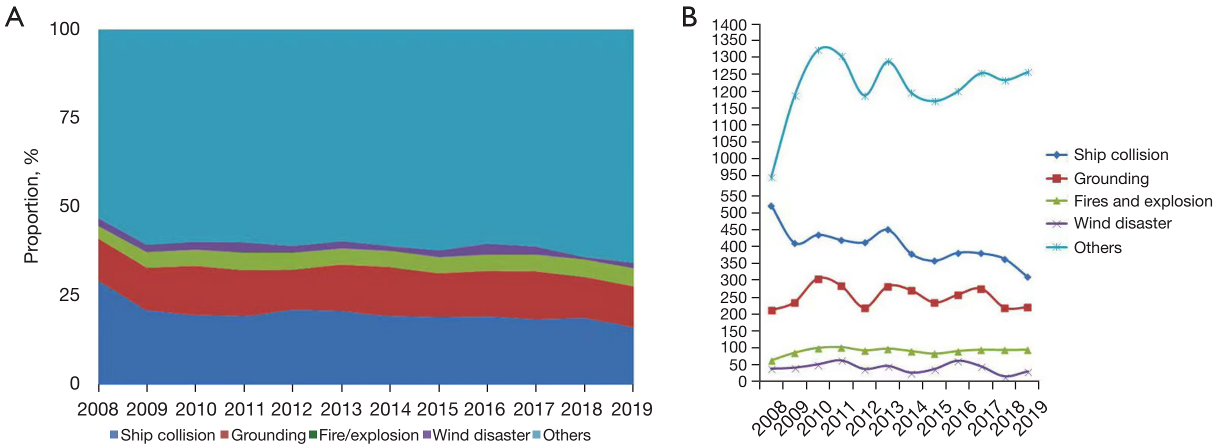

Figure 2 Trends in (A) the proportion and (B) the number of ship accidents by category between 2008 and 2019.

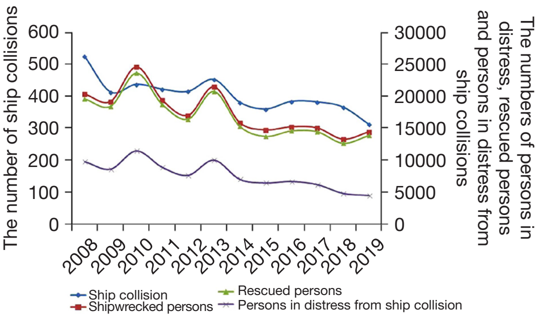

Figure 3 Annual numbers of persons in distress, rescued persons, ship collisions, and persons in distress from ship collisions between 2008 and 2019. The number of ship collisions is indicated by the left coordinate vertical axis, and the numbers of persons in distress, rescued persons, and persons in distress from ship collisions are shown on the right coordinate vertical axis. The annual number of persons in distress is associated with the annual number of ship collisions and the annual number of persons in distress from ship collisions. All the data show similar downward trends, while the annual number of rescued persons is associated with the annual number of persons in distress.

river accidents, and 6.51% occurred in water reservoirs and lakes. However, there was no statistically significant difference in the locations of annual ship accidents. The most frequent types of ship accidents were collisions (18.39%), grounding (12.65%), fire/explosion (4.71%), and wind disasters (1.93%). More than half of the accidents were categorized as having other causes (*Figure 2A*), and there was a statistical difference between ship collisions and other ship accidents ($P<0.05$). Moreover, the annual number of ship collisions showed a fluctuating downward trend between 2008 and 2019 ($P<0.05$; *Figure 2B*); however, there was no statistical difference among the other ship accident categories per annum.

Reduction of persons in distress, ship collision numbers, and deaths

Between 2008 and 2019, a total of 209,948 persons in distress because of ship accidents were reported, showing a significant reduction in the annual numbers of persons in distress and persons in distress in a single accident ($P<0.05$; *Figure 3*). Moreover, the annual number of persons in distress was associated with that of ship collisions ($r=0.92$; $P<0.01$), and of people in distress from ship collisions ($r=0.99$; $P<0.01$; *Figure 3*). However, there was no statistical association between the annual number of persons in distress and the annual number of other cause-related ship accidents, although the annual number of rescued persons was associated with the annual number of persons in distress ($r=0.99$; $P<0.01$; *Figure 3*).

Furthermore, the average annual number of ship accident-related deaths was approximately 670.92 between 2008 and 2019, with the three leading causes of death categorized as other, collision, and wind disaster. The number of deaths from ship collisions showed a statistically significant reduction, although there was no significant reduction in other causes of death. In addition, the annual number of ship collision-related deaths was associated with that of persons in distress ($r=0.70$; $P<0.01$), both of which showed a downward trend ($P<0.05$).

SAR success rate between 2008 and 2019

Between 2008 and 2019, the number of SAR ships and helicopters dispatched did not show any significant changes (*Figure 4*), with a total of 8,051 individual deaths from ship accidents, of which 69.47% was at sea, 24.35% occurred in rivers, and 6.18% occurred in other water reservoirs and lakes. There was no statistical difference in the number of location-related deaths (i.e., in seas, rivers, or lakes). Moreover, there was no significant downward or upward change in the annual mortality rates for different categories of ship accidents between 2008 and 2019 (*Figure 5A*).

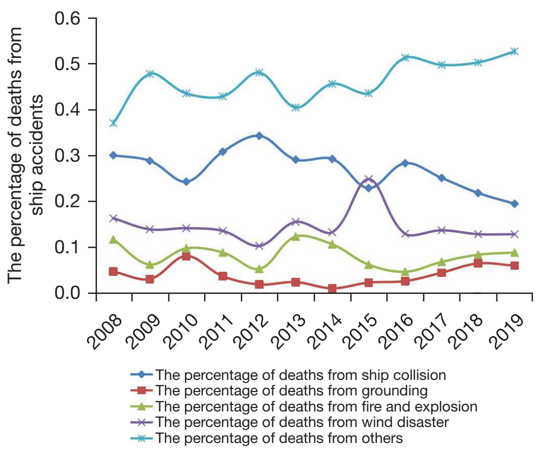

Figure 4 Number of dispatched SAR ships and helicopters between 2008 and 2019. The number of dispatched SAR ships is on the left axis and shows an upward trend, while the number of dispatched SAR helicopters is indicated on the right axis and shows no significant trend upward or downward. SAR, search and rescue.

The average SAR success rate for rescuing persons in distress was 96.17% [standard error (SE) 0.92%], and the SAR success rate for rescuing persons in distress from all categories of ship accidents showed no significant changes between 2008 and 2019 (*Figure 5B*). There was also no association between the number of dispatched SAR forces and the SAR success rate for rescuing persons in distress.

However, there was an increase in the dispatched number of SAR ships between 2008 and 2019, for a total of 209,948 individuals rescued by 104,781 dispatched ships and helicopters in a total of 24,013 SAR operations. Among these, 54.90% were professional rescue ships, 41.29% were nearby passing ships, and 3.81% were helicopters. The average arrival time for nearby passing ships (41.90±7.98 min) was less than that for helicopters (92.40±20.58 min) or professional rescue ships (283.75±40.96 min). Overall, the arrival time for helicopters and professional rescue ships significantly decreased between 2008 and 2019 ($P<0.05$; *Figure 6A*). However, the number of dispatched SAR helicopters did not change, whereas the number of dispatched SAR ships increased between 2008 and 2019 ($P<0.01$; *Figure 6B*).

Discussion

In the current study, we retrospectively retrieved data on the water traffic volume between 2008 and 2019 and divided it into the annual water passenger volume, annual water freight volume, annual number of transportation ships, annual total ship carrying capacity, annual number of persons in distress, annual number of ship accidents, SAR success rate, and dispatched SAR forces and were analyzed

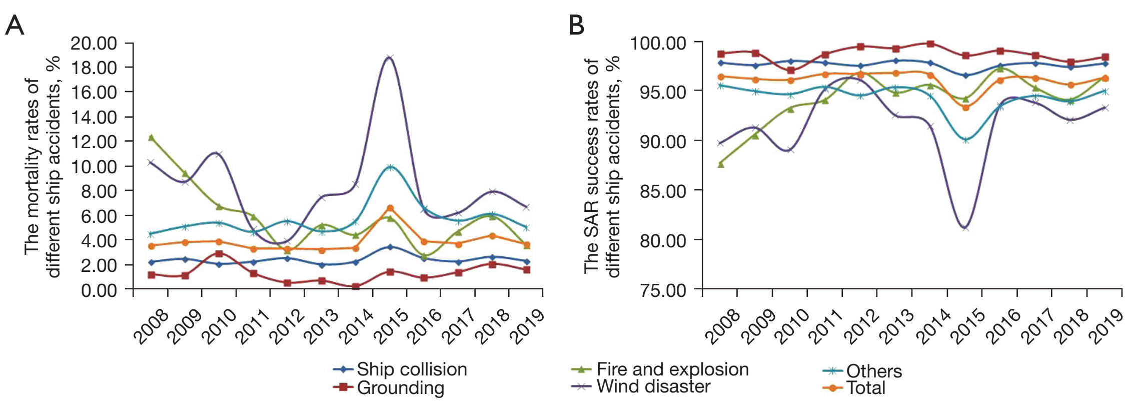

Figure 5 Annual mortality rate (A) and annual SAR success rate (B) for different categories of ship accidents between 2008 and 2019. In all categories of ship accidents, the annual mortality and SAR success rates show no significant changes. SAR, search and rescue.

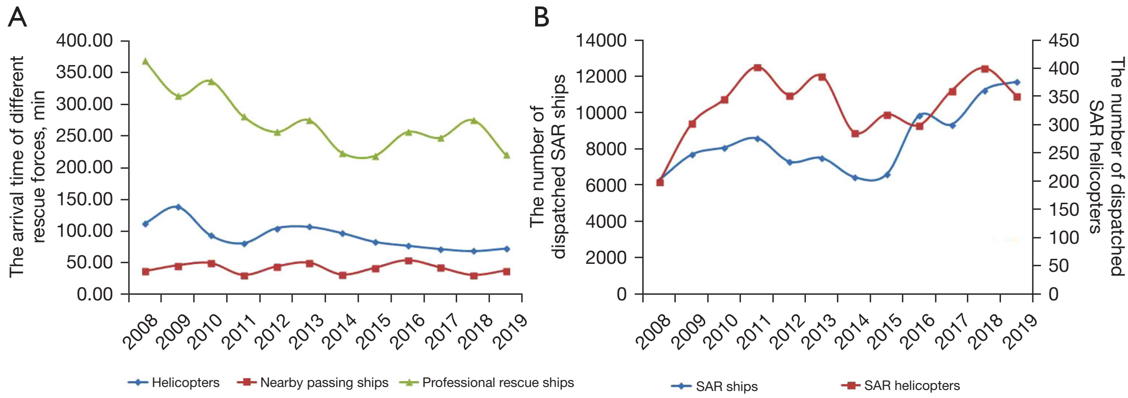

Figure 6 Arrival times of different rescue forces and the dispatch times of SAR ships and helicopters between 2008 and 2019. (A) The arrival time of professional rescue ships and helicopters showed a downward trend, but nearby passing ships provided the quickest rescue efforts. (B) The number of dispatched SAR ships showed an upward trend, whereas the number of dispatched SAR helicopters did not show any significant changes between 2008 and 2019. SAR, search and rescue.

statistically. We found an increase in water traffic volume and ship carrying capacity, but a reduction in the number of annual persons in distress, ship collisions, and ship collision-related deaths between 2008 and 2019. We did not find any significant changes in the locations and causes of annual ship accidents or even the success rate for rescuing people in distress between 2008 and 2019. The dispatched number of helicopters also did not increase during this period, although there was an increase in the dispatched number of SAR ships.

The CMSRC was established in 1989 in China under the Chinese Ministry of Transportation and was initially responsible for maritime and aquatic SAR operations (20). After more than 20 years of development and operation, the CMSRC currently handles all maritime and aquatic ship accidents that occur in Chinese territory. The CMSRC operates 24 h/day to comply with regulation 1/21 of the International Convention for the Safety of Life at Sea (SOLAS 1974), and The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) (20-22). As soon as a request for help is received, SAR workers are immediately contacted by the CMSRC via the coordination of professional rescue ships operated by government or social welfare organization, military ships, nearby fishing ships, passing ships, and/or helicopters to rescue the ships and persons in distress (19-21). To ensure that the SAR commands and coordination instructions are promptly and rapidly implemented and executed, by the end of 2021, the CMSRC has established 14 branches along the approximately 18,000 km of Chinese coastline and the Yangtze River Main Line (20). Additionally, a series of regulations and laws have been formulated and applied by the CMSRC, such as the law of the People's Republic of China on Maritime Traffic Safety, National Maritime Search and Rescue Regulations, and National Maritime Search and Rescue Emergency Plan (20-22). Our current study revealed a reduction in the number of deaths caused by distress, ship collisions, and ship collision-related accidents, although there was an increase in water traffic volume and ship carrying capacity without significant changes in the locations and causes of annual ship accidents or the success rate between 2008 and 2019.

Previous studies have reported that ship collision is the primary cause of serious human casualties (2,23), but in the present study we found that the percentage of deaths from ship collisions ranked second in all categories of ship accidents. Therefore, we speculate that the decline in the number of persons in distress was due to the decline in the number of ship collisions. In China between 2008 and 2019, there was an increase in ship cargo and passenger capacity but a decrease in the number of transportation ships, indicating that the size of the ships increased in China. According to the regulations of the CMSRC and International Maritime Organization, ships >25 m in length must be equipped with an automatic identification system, vessel traffic services (VTS), and modern navigational devices to provide related information and real-time data (20-25). VTS and other navigation services, as well as better ship design, can improve the safety and efficiency of ship traffic through monitoring of the ship's position, course, speed, and identity for better navigation in the appropriate watercourse and therefore reduce the risk of ship collisions (24,26,27). As a result, the number of people in distress and the number of deaths from ship collisions decreased in concert with the reduction in the number of ship collisions, as observed in our current study.

Weng and Yang analyzed 10 years of global ship accident data and showed that the rates of fatal accidents and deaths were higher for ship collisions, fire and explosions, contact, grounding, sinking accidents in hostile weather, and dark conditions (28). Roberts also reported that the major cause of ship-related deaths in the UK between 1919 and 2005 was ship collisions in poor visibility, vessels foundering during typhoons, storms, and severe gales, and explosions in the cargo compartment (9). Our current data are in agreement with that study (9) and we found that >50% of deaths were from ship collisions, grounding, fire and explosions, and wind disasters. Previous studies showed a continuous reduction in the number and severity of ship accidents due to improvements in ship safety in the UK since 1900 (2), and a significant reduction in deaths for all the main types of ship accidents in the UK between 1919 and 2005 (9). However, the significant reduction in deaths over time due to ship collisions did not lead to a corresponding reduction in vessel accidents overall in the present study, which concurred with a report from Roberts *et al.* showing that a significant reduction in deaths over time due to grounding did not cause a reduction in deaths for vessel accidents overall when no changes in other types of vessel accidents in the UK occurred between 1948 and 2008 (29). We also noticed that approximately 46.07% of deaths were from other types of accidents, which may have partly resulted from the foundering of fishing vessels and work injuries among fishermen. According to Danish fishing ship accident reports, the fatal accident rates among fishermen remained high because of difficult embarking/disembarking conditions such as darkness, alcohol intoxication, and foundering/capsizing due to stability changes even after regular and repeated safety training were conducted to reduce such risks (30). Therefore, it is necessary to develop and improve water SAR to better save lives, especially in tough environments.

However, our current study showed that the SAR success rate for persons in distress did not increase significantly, although the dispatched number of SAR ships significantly increased since 2008. This result might be due to delayed or prolonged arrival times for rescue ships, which are usually several hours away offshore (10,15,31,32). Although the arrival time of professional rescue ships has been decreasing, it still far exceeds “the 10 platinum minutes” and “the golden hour”. To date, there are only 24 coastal rescue bases spread along the Chinese coastline, which is significantly fewer than the 54 rescue bases spread along the 2,389 km of coastline in Germany (33), resulting in accident scenes that are more likely to be far from rescue bases. According to Nicholl *et al.*, a 10-km increase in distance from a hospital was associated with a 1% absolute increase in mortality (34); thus, “the 10 platinum minutes” and “the golden hour” were proposed for the resuscitation of severely injured patients (14). Hypertonic seawater, which has low temperature, alkalinity, and high permeability can accelerate the death of injured persons in distress by inducing vascular leakage and cell dehydration and exacerbating microcirculation and energy metabolic aberrations in injured tissues (13,31). A previous study showed that the risk of drowning was increased in rivers geographically located far from medical facilities (14). Thus, to reduce the death rate, the arrival time of the medical rescue team should be significantly shortened, which in China can be achieved by increasing the frequency of rescue ship cruising or establishing more rescue bases.

Furthermore, helicopters with advanced cardiac life support (ACLS) personnel might increase the survival rate of injured individuals (12,15,34). With improvements in VTS and communication technology, the accident site could be better and precisely localized to reduce the arrival time of the helicopter rescue team. In our present study, we found that helicopter rescue was able to eliminate nearly two-thirds of the arrival time of professional rescue ships. However, to date, there is no increase in the number of helicopters dispatched by maritime and aquatic SAR operations, which might be another reason for the lack of improvement in the SAR success rate since 2008. In addition, high quality prehospital care has been shown to be essential for increasing the survival possibility of severely injured individuals (33). Currently, the 22 h of academic training and 16 h of practical training for SAR staff in China are significantly shorter than the 1-week academic and practical training hours in Germany (9,15). The training for basic life support (BLS), wound suture, and fracture splint fixation for Chinese SAR staff also does not meet the needs for maritime and aquatic medical rescue duty (16,20). For example, severely injured persons in distress urgently require ACLS to save their lives at the scene, including securing the airway by endotracheal intubation, hindering exsanguination, inserting intravenous lines, and initiating fluid resuscitation therapy (15,35,36). Thus, more and better training of SAR staff in China is urgently needed to improve the medical emergency capabilities of rescue personnel.

In addition, we noted that the arrival time of nearby passing ships was within the range of "the golden hour". Therefore, it may be worth recommending and grouping multiple ships to sail adjacent to provide help in case an accident occurs. According to previous studies, immediate bystander cardiopulmonary resuscitation increased the survival of out-of-hospital cardiac arrest individuals by 2- to 3-fold (37,38). However, only 25.6% of laypersons attend BLS training in China (39). Thus, it is crucial to increase the popularity of seafarer BLS training. Overall, a decline in maritime and aquatic casualties relies on the prevention of ship accidents, and reducing the number of persons in distress through improvements in the formulation of regulations and policies. In addition, shortening the medical arrival time, strengthening helicopter rescue with ACLS-trained personnel, and increasing the ability for nearby ships to render help will improve the SAR success rate for persons in distress.

Acknowledgments

Funding: This study was supported in part by grants from the Medical Science Project of Shanghai Science and Technology Commission (#19411963000), The Key Disciplines Group Construction Project of the Pudong Health Bureau of Shanghai (#PWZxq2017-13), and The Key Project of Hunan Provincial Science and Technology Innovation (No. 2020SK1011).

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://atm.amegroups.com/article/view/10.21037/atm-22-4530/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-4530/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Health Research Ethics Committee of the Shanghai East Hospital of Tongji University. The requirement for individual consent was waived by the committee.

References

1. Kosowska-Stamirowska Z. Network effects govern the evolution of maritime trade. Proc Natl Acad Sci U S A 2020;117:12719-28.
2. Carter T, Williams JG, Roberts SE. Crew and passenger deaths from vessel accidents in United Kingdom passenger ships since 1900. Int Marit Health 2019;70:1-10.
3. Devault DA, Beilvert B, Winterton P. Ship breaking or scuttling? A review of environmental, economic and forensic issues for decision support. Environ Sci Pollut Res Int 2017;24:25741-74.
4. Hetherington C, Flin R, Mearns K. Safety in shipping: the human element. J Safety Res 2006;37:401-11.
5. World Health Organization (WHO). Global report on drowning: preventing a leading killer. 2014. Available online: file:///C:/Users/Administrator/Downloads/9789241564786_eng.pdf
6. World Health Organization (WHO). Drowning. 2020. Available online: https://www.who.int/news-room/fact-sheets/detail/drowning
7. Roberts SE, Nielsen D, Kotłowski A, et al. Fatal accidents and injuries among merchant seafarers worldwide. Occup Med (Lond) 2014;64:259-66.
8. Case SL, Lincoln JM, Lucas DL. Fatal Falls Overboard in Commercial Fishing - United States, 2000-2016. MMWR Morb Mortal Wkly Rep 2018;67:465-9.
9. Roberts SE. Fatal work-related accidents in UK merchant shipping from 1919 to 2005. Occup Med (Lond) 2008;58:129-37.
10. Erasmus E, Robertson C, van Hoving DJ. The epidemiology of operations performed by the National Sea

Rescue Institute of South Africa over a 5-year period. Int Marit Health 2018;69:1-7.
11. He Y. Research on evaluation and promotion of maritime search and rescue service in tianjin [thesis]. 2020.
12. Dahl E. Large-scale helicopter rescue of cruise passengers and freighter crew off the coast of Norway in stormy weather. Int Marit Health 2019;70:79-81.
13. Ma J, Wang Y, Wu Q, et al. Seawater immersion aggravates burn-associated lung injury and inflammatory and oxidative-stress responses. Burns 2017;43:1011-20.
14. Peden AE, Franklin RC, Leggat PA. Cardiopulmonary resuscitation and first-aid training of river users in Australia: A strategy for reducing drowning. Health Promot J Austr 2019;30:258-62.
15. Montocchio-Buadès C, Daurat M, Ducombs M, et al. Management of a polytrauma in the maritime environment. Int Marit Health 2018;69:126-8.
16. Press Office of the Ministry of Transport of the People's Republic of China. Chinese crew development report in 2020. 2021. Available online: https://xxgk.mot.gov.cn/2020/jigou/haishi/202106/P020210625407266424238.pdf
17. The Ministry of Transport of the People's Republic of China. Water transport market developments and market outlook in 2021. 2022. Available online: https://xxgk.mot.gov.cn/2020/jigou/syj/202203/t20220317_3646405.html
18. Roberts SE, Carter T. Causes and circumstances of maritime casualties and crew fatalities in British merchant shipping since 1925. Int Marit Health 2018;69:99-109.
19. Mazaheri A, Goerlandt F, Montewka J, et al. A decision support tool for VTS centers to detect grounding candidates. International Journal of Marine Navigation and Safety of Sea Transportation 2012;6:337-43.
20. China maritime search and rescue center. Institutional functions. Available online: https://zizhan.mot.gov.cn/sj2019/soujiuzx/201809/t20180920_3090934.html
21. Zhang W, Yan X, Yang J. Optimized maritime emergency resource allocation under dynamic demand. PLoS One 2017;12:e0189411.
22. China maritime search and rescue center. Policies and regulations. Available online: http://zizhan.mot.gov.cn/sj2019/soujiuzx/faguizc_sjzx/index_1.html
23. Chauvin C, Lardjane S, Morel G, et al. Human and organisational factors in maritime accidents: analysis of collisions at sea using the HFACS. Accid Anal Prev 2013;59:26-37.
24. Wu H, Mei X, Chen X, et al. A novel cooperative localization algorithm using enhanced particle filter technique in maritime search and rescue wireless sensor network. ISA Trans 2018;78:39-46.
25. Wang X, Zhang B, Zhao X, et al. Exploring the Underlying Causes of Chinese Eastern Star, Korean Sewol, and Thai Phoenix Ferry Accidents by Employing the HFACS-MA. Int J Environ Res Public Health 2020;17:4114.
26. Karbowska-Chilinska J, Koszelew J, Ostrowski K, et al. Beam Search Algorithm for Ship Anti-Collision Trajectory Planning. Sensors (Basel) 2019;19:5338.
27. Praetorius G, Lützhöft M. Decision support for vessel traffic service (VTS): user needs for dynamic risk management in the VTS. Work 2012;41 Suppl 1:4866-72.
28. Weng J, Yang D. Investigation of shipping accident injury severity and mortality. Accid Anal Prev 2015;76:92-101.
29. Roberts SE, Jaremin B, Marlow PB. Human and fishing vessel losses in sea accidents in the UK fishing industry from 1948 to 2008. Int Marit Health 2010;62:143-53.
30. Laursen LH, Hansen HL, Jensen OC. Fatal occupational accidents in Danish fishing vessels 1989-2005. Int J Inj Contr Saf Promot 2008;15:109-17.
31. Dittmann F, Dirksen-Fischer M, Harth V, et al. The rescue of refugees: a challenge for the merchant fleet. Int Marit Health 2015;66:252-7.
32. Yang C, Gao J, Du J, et al. Understanding the Outcome in the Chinese Changjiang Disaster in 2015: A Retrospective Study. J Emerg Med 2017;52:197-204.
33. Buschmann C, Niebuhr N, Schulz T, et al. "SAR-First-Responder Sea" - backgrounds to a medical education concept in German SAR service. Int Marit Health 2009;60:43-7.
34. Nicholl J, West J, Goodacre S, et al. The relationship between distance to hospital and patient mortality in emergencies: an observational study. Emerg Med J 2007;24:665-8.
35. Beuran M, Paun S, Gaspar B, et al. Prehospital trauma care: a clinical review. Chirurgia (Bucur) 2012;107:564-70.
36. Teo KA, Chong TF, Liow MH, et al. Medical Support for Aircraft Disaster Search and Recovery Operations at Sea: the RSN Experience. Prehosp Disaster Med 2016;31:294-9.
37. Nishi T, Maeda T, Takase K, et al. Does the number of rescuers affect the survival rate from out-of-hospital cardiac arrests? Two or more rescuers are not always better than one. Resuscitation 2013;84:154-61.
38. Tanaka Y, Taniguchi J, Wato Y, et al. The continuous quality improvement project for telephone-assisted

instruction of cardiopulmonary resuscitation increased the incidence of bystander CPR and improved the outcomes of out-of-hospital cardiac arrests. Resuscitation 2012;83:1235-41.
39. Chen M, Wang Y, Li X, et al. Public Knowledge and Attitudes towards Bystander Cardiopulmonary Resuscitation in China. Biomed Res Int 2017;2017:3250485.

(English Language Editor: K. Brown)

Cite this article as: Huang J, Han N, Jiang BQ, Cao Y, Han XT. Water search and rescue (SAR) for ship accidents in China: analysis of 12 years' data. Ann Transl Med 2022;10(22):1207. doi: 10.21037/atm-22-4530

