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Time Pattern of Presentation of Victims of High-Speed Passenger Ferry Mass Casualty Incidents to the Emergency Department

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Abstract

Objective: Mass Casualty Incidents (MCIs) involving high-speed passenger ferries (HSPFs) may result in the dual-wave phenomenon, in which the emergency department (ED) is overwhelmed by an initial wave of minor injuries, followed by a second wave of more seriously injured victims. This study aimed to characterize the time pattern of ED presentation of victims in such accidents in Hong Kong.
Methods: All HSPF MCIs from 2005 to 2015 were reviewed retrospectively, with the time interval from accident to ED registration determined for each victim. Multivariable linear regression was used to identify independent factors associated with the time of ED presentation after the accidents.
Results: Eight MCIs involving 492 victims were identified. Victims with an Injury Severity Score (ISS) ≥ 9 had a significantly shorter median time interval compared to those with minor injuries. An ISS ≥ 9 and evacuation by emergency service vessels were associated with a shorter delay in ED arrival, whereas ship sinking, accident at nighttime, and a longer linear distance between the accident and receiving ED were associated with a longer delay.
Conclusion: The dual-wave phenomenon was not present in HSPF MCIs. Early communication is the key to ensure early resource mobilisation and a well-timed response.

Introduction

Maritime disasters involving high-speed passenger ferries (HSPFs), though not common, can lead to mass casualties. High-speed collisions result in blunt trauma similar to road vehicle crash injuries.[1] Sinking vessels can cause fatalities due to drowning. Rescue is often challenging due to the remoteness of the accident from the shore, large numbers of victims per accident, limited deck space, and on-board medical resources, as well as unfavorable weather, and rough sea conditions.[2] Previous reports in literature have highlighted several important problems in such rescues, including difficulty in victim evacuation from the vessels, insufficient communication, and lack of cooperation between responding agencies.[3,4] Emergency departments (EDs) are at the receiving end of the chain of rescue. It is important to mobilize appropriate personnel and resources in a timely manner when responding to such accidents, which often occur with little or no warning.

However, ED response to HSPF accidents may be impeded by a phenomenon called 'the dual-wave phenomenon.' This phenomenon refers to a disaster response situation where the ED is overwhelmed by an initial wave of minor injuries, followed by a second wave of victims of more serious injuries. This has been mentioned in many textbooks and articles written on disaster management,[5,6] and included in simulation models of hospital response to mass casualty incidents (MCIs).[7] In the context of HSPF MCI, such a phenomenon was postulated to be possible, given the limited access to the victims on-board, and the difficulty in transporting seriously injured victims out of damaged vessels. However, studies on HSPF MCI are lacking.

There is a need to understand the time pattern of ED presentations of victims, the time intervals between the accidents, and various key clinical activities such as X-ray examination, hospital admission, intensive care unit (ICU) admission, and surgical operations, to inform hospital disaster planning for HSPF MCIs, which requires a concerted response across different clinical departments. This study was conducted to characterize the time pattern of ED presentation of victims, and various key clinical activities after the accidents, and to identify independent factors associated with the time of ED presentation after the accidents. The hypothesis was that the dual-wave phenomenon might be present in such accidents.

Methods

This was a retrospective study on the victims of HSPF MCIs received by the public EDs of 7 major hospitals around Victoria Harbor in Hong Kong from January 1, 2005, to December 31, 2015. These 7 hospitals comprised 3 trauma centers: Queen Mary Hospital, Queen Elizabeth Hospital, and Princess Margaret Hospital; and 4 district hospitals: Ruttonjee Hospital, Pamela Youde Nethersole Eastern Hospital, St John Hospital, and Kwong Wah Hospital. Ethical approval was obtained from the institutional review boards of all participating hospitals (HKU/HA HKW IRB UW16-318, HKEC-2016-110, KC/KE-17-0010/ER-2, KW/EX-17-025[108-04]) prior to the commencement of the study. Patient consent was waived because data were collected and analyzed anonymously.

An MCI was defined as an incident involving 8 or more casualties, as commonly adopted by all government rescue agencies and public EDs in Hong Kong.[8] HSPF accidents that involved fewer than 8 casualties were excluded because they could be routinely managed by most EDs without mobilizing extra personnel and resources. For the definition of HSPF, the local Marine Department classification was followed when screening for accidents for inclusion in our study.[9]

Data were obtained from the following sources:

1) Details of the accidents, including the date, time, and Global Positioning System (GPS) coordinates, as well as vessels involved, circumstances, and number of occupants on board, were sourced from the investigation reports published by the Marine Department.
2) Clinical records of the victims involved in the selected MCIs were extracted from electronic databases, including the Disaster Group of the Accident and Emergency Information System (AEIS), which were activated in the event of an MCI in the receiving hospitals, and the Clinical Management System of the study hospitals.
3) Autopsy reports, where available, were accessed from the coroner's court for victims who died from the included accidents.

When analyzing the time pattern of ED presentation, the time interval (in hours) from the official time of each accident, as stated in the Marine Department investigation report, and the ED registration time of each victim was calculated. For victims who attended more than 1 ED or an ED multiple times after the accident, only the first ED registration was counted. The time intervals between the time of accident and time of various clinical activities, including the first X-ray examination, hospital admission, and intensive care unit (ICU) admission, as well as surgical operations, were also calculated. The number of events was recorded at 15-minute intervals based on the recommendations made by the Academy for Emergency Management and Disaster Medicine (EMDM Academy) Consensus Group.[10] Victims who presented more than 8 hours after the accident, many of whom attended the ED several days after the accidents for minor injuries, were excluded due to their limited impact on the initial emergency response, and also because their time data would skew the overall analysis (data not shown).

On ED arrival, all victims were triaged by nurses according to the prevailing Hong Kong Accident and Emergency Triage Guidelines uniformly adopted by all public EDs. The 5 categories are 1 (critical); 2 (emergent); 3 (urgent); 4 (semi-urgent); and 5 (non-urgent) based on the severity of the presenting condition and stability of vital signs.[11] For each incident, the proportion of victims in each triage category was reported. Severity of injury was determined based on the clinical notes, radiology reports, operative records, and autopsy reports where available. A trained coder assigned Abbreviated Injury Scale (AIS) to each injury by body region on a 6-point scale according to the AIS 2015 Dictionary: AIS 1 (minor); AIS 2 (moderate); AIS 3 (serious); AIS 4 (severe); AIS 5 (critical); and AIS 6 (nonsurvivable).[12] The Injury Severity Score (ISS) was calculated by selecting the 3 ISS regions with the highest AIS and summing their squared AIS. An ISS of 75 was allotted if any AIS was 6. Any injury of undetermined severity was allotted an AIS of 9 and an ISS of 99.[13] Victims with an ISS 99 were excluded from analysis.

In this study, an ISS $\geq$ 9 was used as the cut-off point to identify patients with moderate or major trauma.[14] Victims with an ISS < 9 were considered as having minor injuries. This cut-off point has been validated in large trauma registries involving different ethnicity, gender, and age group.[15,16] An ISS $\geq$ 9 is associated with a higher mortality[15] and a longer hospital length of stay.[16]

Analysis

Missing values were not imputed. The characteristics of victims and the time pattern of ED presentation were analyzed using descriptive statistics. The GPS coordinates of the accident locations and the 7 receiving hospitals were plotted on Google Maps and Google Earth (Google, Inc., Mountain View, CA, USA). The geographic distance between the accident sites and receiving EDs of individual victims was calculated based on their GPS coordinates using the Haversine Formula,[1] which determines the great-circle distance between 2 points over the earth's surface. The median time of ED registration after the accident between victims with moderate or major trauma (ISS $\geq$ 9) and those with minor injuries (ISS < 9) was compared using the Mann–Whitney U test.

Multivariable linear regression was then performed to identify independent factors associated with the time of ED presentation after the accidents, taking into account patient factors, such as age and severity of injury (ISS $\geq$ 9 vs ISS < 9); and circumstantial factors, including the linear distance between the accident site and receiving ED, daytime or night-time occurrence of the accident, whether there was sinking of a vessel, and whether there was vessel evacuation and transportation by emergency service vessels on the spot of accident. We did not enter visibility into the regression model because of the significant collinearity of visibility and night-time occurrence of accident (Spearman correlation = 1.0, $P < 0.001$). In practice, the time of accident occurrence is more easily available to the receiving EDs. Also, the weather conditions varied

[1]https://www.movable-type.co.uk/scripts/latlong.html

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Table 1. Details of the mass casualty incidents that involved high-speed passenger ferry

Incident	Date and time of the accidents	Brief description of the accident	Visibility	Weather condition	Number of persons on board
1	February 17, 2005; 08:12	A HSPF (at 40 knots) collided with a container (at 9 knots). After collision, the ferry returned under its own power to the pier, where victims were sent to hospitals.	300m	Cloudy with fog patches	156
2	March 28, 2005; 09:02	A HSPF (at 29 knots) collided with a dumb steel lighter (at 4.2 knots). After collision, the ferry returned under its own power to the pier, where victims were sent to hospitals.	550m	Foggy	57
3	July 1, 2008; 20:17	A HSPF (at 2 – 3 knots) collided with another ferry while overtaking it. Both vessels returned to piers after collision, where victims were sent to hospitals.	9260m	Overcast	HSPF: 150 Ferry: 256
4	October 21, 2011; 05:10	A HSPF collided with a mooring dolphin inside a typhoon shelter soon after departure from a pier. The victims were evacuated from the damaged ferry and transported by emergency service and other nearby vessels to the pier.	Not reported	Not reported	144
5	October 1, 2012; 20:20	A HSPF (at 24.5 knots) collided with another ferry (at 11.5 knots). The latter vessel sank after the collision. The ferry proceeded to a pier under its own power after collision. Victims from the sunk ferry were rescued by emergency service and other nearby vessels. Penetration dives into the hull of the sunk ferry were conducted by Fire Services divers but no survivors were identified.	10 000m	Good weather	HSPF: 99 Ferry: 127
6	November 29, 2013; 01:14	A HSPF hit an unknown submerged object during cruise at 44 knots. The ferry returned under its own power to the pier, where victims were sent to hospitals.	18 520m	Good weather	116
7	May 21, 2014; 22:51	A HSPF (at 40 knots) collided with a river trade vessel (at 6 knots). After collision, the ferry returned under its own power to the pier, where victims were sent to hospitals.	18 520m	Cloudy	170
8	October 25, 2015; 18:39	A HSPF hit an unknown submerged object during cruise at 39.5 knots. The victims were evacuated from the damaged ferry and transported by emergency service vessels to a pier, where they were sent to hospitals.	9260m	Good weather	174

Abbreviations: HSPF, high-speed passenger ferry

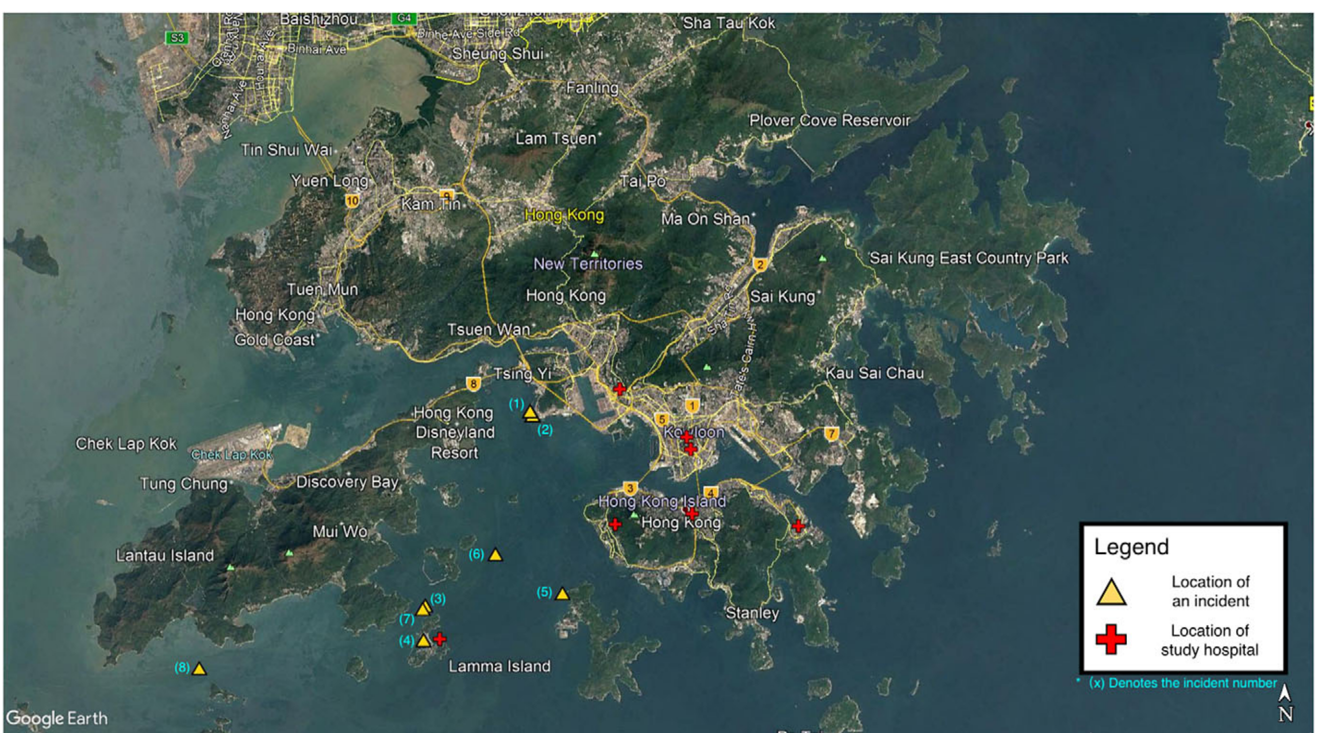

Figure 1. The locations of the mass-casualty incidents that involved high-speed passenger ferries and the locations of the receiving study hospitals, respectively.

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Table 2. The number and triage categories of victims presenting to ED within 8 hours of accident

Incident	Number of victims presenting to the study hospitals within 8 hours	Triage category 1 – critical (%)	Triage category 2 – emergent (%)	Triage category 3 – urgent (%)	Triage category 4 – semi-urgent (%)	Triage category 5 – non-urgent (%)
1	50	1 (2.0)	3 (6.0)	7 (14.0)	39 (78.0)	0 (0)
2	15	0 (0)	0 (0)	3 (20.0)	12 (80.0)	0 (0)
3	15	0 (0)	0 (0)	0 (0)	15 (100)	0 (0)
4	75	0 (0)	1 (1.3)	10 (13.3)	62 (82.7)	2 (2.7)
5	103	12 (11.7)	2 (1.9)	25 (24.3)	64 (62.1)	0 (0)
6	85	0 (0)	3 (3.5)	24 (28.2)	58 (68.2)	0 (0)
7	34	0 (0)	1 (2.9)	2 (5.9)	31 (91.2)	0 (0)
8	115	2 (1.7)	12 (10.4)	28 (24.3)	73 (63.5)	0 (0)

Table 3. Characteristics of victims

	All victims (n = 492)	Victims with ISS < 9 (n = 449)	Victims with ISS ≥ 9 (n = 43)
Median age (range)	43.0 years (2.0 – 85.0 years)	43.0 years (2.0 – 85.0 years)	51.0 years (2.0 – 82.0 years)
Male gender (%)	263 (53.5)	244 (54.3)	19 (44.2)
Mechanism of injury			
Hitting the seat in front (%)	124 (25.2)	117 (26.1)	7 (16.3)
Fall into water (%)	62 (12.6)	47 (10.5)	15 (34.9)
Fall onto floor (%)	37 (7.5)	33 (7.3)	4 (9.3)
Hitting a hard object (%)	40 (8.1)	38 (8.5)	2 (4.7)
Sprain injury (%)	12 (2.4)	12 (2.7)	0 (0)
Cut by glass (%)	9 (1.8)	9 (2.0)	0 (0)
Thrown up and down (%)	6 (1.2)	2 (0.4)	4 (9.3)
Other mechanisms (%)	9 (1.8)	9 (2.0)	0 (0)
Combination of two or more mechanisms (%)	23 (4.7)	19 (4.2)	4 (9.3)
Unknown mechanism (%)	170 (34.6)	163 (36.3)	7 (16.3)
Median time interval from the accident to ED registration (IQR)	3.4 h (2.8 –4.2 h)	3.5 h (2.9 –4.2 h)	2.8 h (1.8 –4.5 h)
Triage category			
Category 1 (%)	15 (3.0)	5 (1.1)	10 (23.3)
Category 2 (%)	22 (4.5)	13 (2.9)	9 (20.9)
Category 3 (%)	99 (20.1)	82 (18.3)	17 (39.5)
Category 4 (%)	354 (72.0)	347 (77.3)	7 (16.3)
Category 5 (%)	2 (0.4)	2 (0.4)	0 (0)
Any drowning (%)	15 (3.0)	0 (0)	15 (34.9)
Median ISS (IQR)	1.0 (1.0 – 2.0)	1.0 (1.0 – 2.0)	10.0 (9.0 – 25.0)
X–ray examination (%)	390 (79.3)	356 (79.3)	34 (79.1)
Hospital admission (%)	99 (20.1)	65 (14.5)	34 (79.1)
ICU admission (%)	15 (3.0)	2 (0.4)	13 (30.2)
Surgical operation (%)	18 (3.7)	8 (1.8)	10 (23.3)
Episode death (%)	11 (2.2)	0 (0)	11 (25.6)

Abbreviations: AIS, Abbreviated Injury Scale; ICU, Intensive Care Unit; IQR, Interquartile Range; ISS, Injury Severity Score

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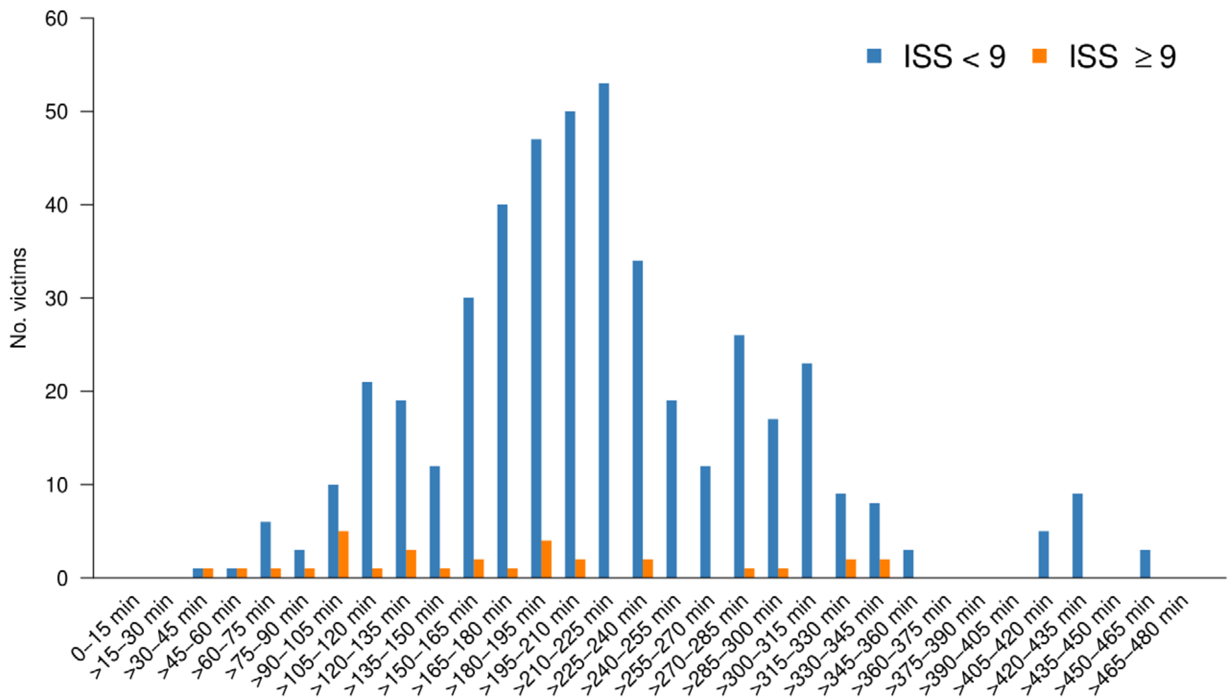

Figure 2. Distribution of time interval from accident to ED registration of victims with ISS < 9 and ISS ≥ 9.

considerably across different accidents, and it was difficult to dichotomize them. Therefore, we did not enter weather conditions into the regression model.

Statistical analysis was performed using Statistical Package for the Social Sciences Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA). *A P* value of < 0.05 was considered statistically significant.

Results

Over the study period, 8 HSPF MCIs were identified. The details of the accidents are shown in Table 1. Figure 1 shows the location of the accidents and receiving hospitals. All accidents were caused by collision of a HSPF with another vessel or object in the sea. In most incidents, the damaged vessels were able to return under their own power to the shore, where victims were transported to various hospitals nearest to the shore gathering point by ground and air transport. In 2 of the accidents (Incidents 4 and 8), evacuation from the damaged vessels was needed and the victims were transported by emergency service vessels or nearby civilian vessels to the shore, then by ground transport to the receiving hospitals. One accident (Incident 5) caused the sinking of a ferry and drowned many victims on board. All victims were rescued by nearby civilian and emergency service vessels and transported to the shore. The median distance between the accident site and the receiving hospital was 12.3 km (IQR 9.4 – 22.9 km).

A total of 492 victims presented to the EDs of the study hospitals within 8 hours of the accidents, with the number of victims per incident ranging from 15 to 115. Most victims were triaged as semi-urgent (Table 2). The median age of the victims was 43.0 years (range 2–85 years) and there was no gender preponderance. The characteristics of the victims are presented in Table 3. Most injuries were minor and the median ISS for the whole cohort was 1.0 (IQR 1.0 – 2.0). None had an ISS of 99 (undetermined severity of injury). Forty-three (43) victims (8.7%) had moderate or major trauma (ISS ≥ 9), and most of the victims (79.3%) required an X-ray. The proportions of victims who required hospitalization, ICU admission, and surgical operation were 20.1%, 3.0%, and 3.7%, respectively. Eleven victims (2.2%) died, mostly due to drowning.

Overall, the median time interval between accident and ED registration was 3.4 hours (IQR 2.8 – 4.2 hours). The distribution of time interval from accident to ED registration of victims with an ISS ≥ 9 and ISS < 9 is shown in Figure 2. Comparing victims with an ISS ≥ 9 to those with a lower ISS, the median time interval from accident to ED registration (2.8 vs 3.5 hours, *P* = 0.007) was significantly shorter for those with moderate or major trauma. Figure 3 and Supplementary Table 1 show respective time intervals stratified by the severity of injury and individual accidents. In Incidents 4 and 5, the median time intervals to ED registration were significantly shorter for victims with moderate or major trauma. Although the median time interval appeared to be longer for those with ISS ≥ 9 in incident 8, the difference did not reach statistical significance.

The distribution of time interval from accident to various clinical activities is shown in Figure 4. The median time intervals between the accident and X-ray, hospital admission, ICU admission, and surgical operation were 4.4 hours (IQR 3.7 – 5.4 hours), 5.5 hours (IQR 4.4 –6.9 hours), 4.4 hours (IQR 3.0 – 19.6 hours), and 27.5 hours (IQR 6.7 – 68.2 hours), respectively. Counting from the time of ED registration, the corresponding figures were 0.6 hours (0.4 - 1.1 hours), 1.8 hours (1.1 - 2.3 hours), 2.2 hours (1.1 - 14.2 hours), and 22.6 hours (3.2 - 63.2 hours), respectively.

Multivariable linear regression showed that a longer time interval from accident to ED registration was significantly associated with the sinking of a vessel (*P* < 0.001), accident at nighttime (*P* < 0.001), as well as a longer linear distance between the accident site and receiving ED (*P* < 0.001). An ISS ≥ 9 (*P* = 0.04) and vessel evacuation and transportation by emergency service vessels on the spot of accident (*P* < 0.001) were associated with a significantly shorter time interval. Patient's age was not significantly associated with the

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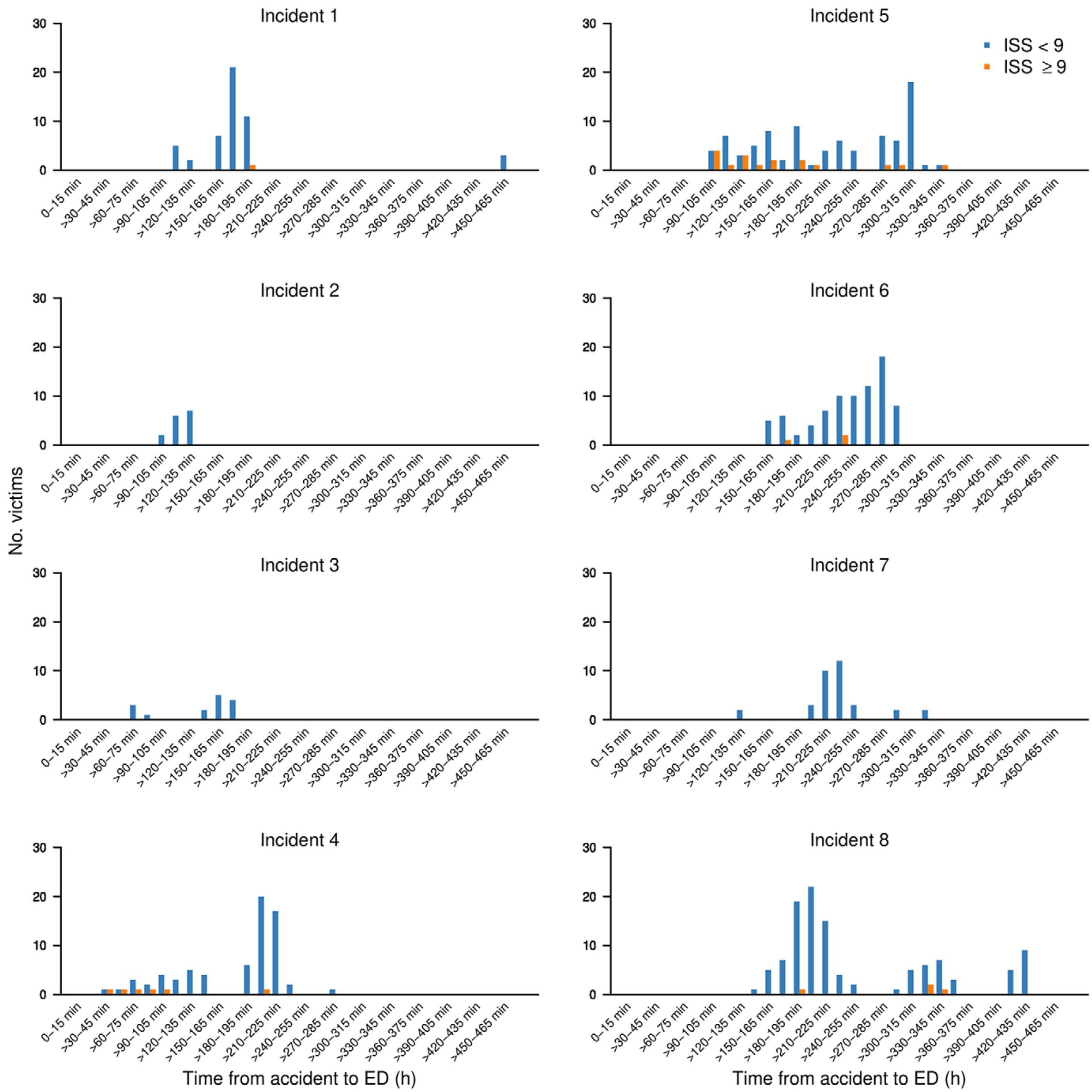

Figure 3. Distribution of time interval from accident to ED registration of victims stratified by accident and severity of injury.

time interval after adjusting for the circumstantial factors and severity of injury (Table 4). The adjusted R-squared of the regression model was 0.3, indicating that it could explain 30% of the variance in the time interval from accident to ED registration.

Discussion

Accidents involving HSPFs have been reported in Canada,[17] Japan,[18] Spain,[19] and the USA.[20,21] When compared with conventional ocean-going vessels, high-speed vessels are more liable to collision, grounding, and other contact events.[22] Analysis of past accidents has shown that the key causes are human factors, such as failure to maintain a proper lookout because of overconfidence of bridge personnel,[19] and failure to maintain a safe speed due to pressure to keep to schedule.[19,22] Though many of these accidents have resulted in mass casualties, the literature still lacks studies evaluating emergency hospital response to such accidents with the aim to inform disaster planning.

This study showed a time lag of 2 to 3 hours between the accident and ED arrival of the victims across different accidents. This finding is consistent with that reported for similar accidents in the literature. Lockey et al reported that it took 1 hour and 17 minutes to evacuate 300 passengers from a listing catamaran, despite no injuries being sustained during the collision between the catamaran

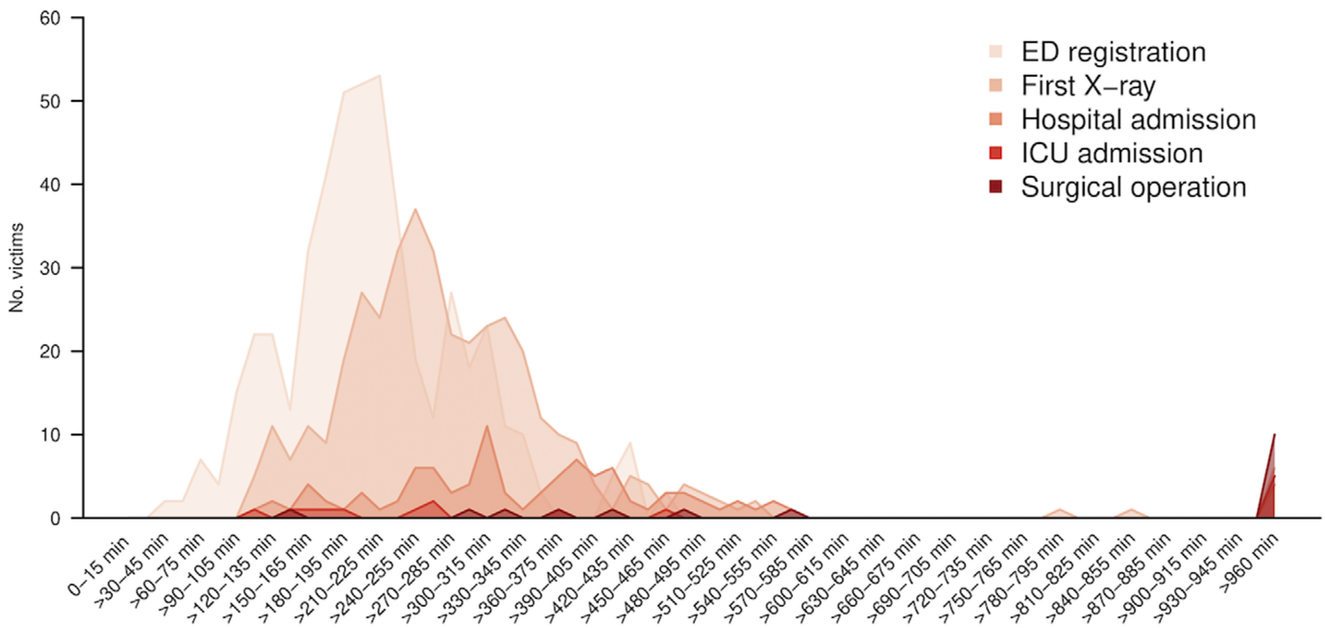

Figure 4. Distribution of time interval from accident to various clinical activities.

Table 4. Multi-variable linear regression model in predicting the time interval between the accident and ED registration

Factor	Beta coefficient	95% CI	*P* value
Ship sinking	0.98	0.67 to 1.29	< 0.001
Night–time accident	0.67	0.35 to 0.99	< 0.001
Linear distance between the accident site and receiving ED	0.08	0.07 to 0.09	< 0.001
ISS ≥ 9	– 0.37	– 0.71 to – 0.02	0.04
Vessels evacuation and transportation by emergency service vessels on the spot of accident	– 0.92	– 1.19 to – 0.65	< 0.001
Age	0.004	– 0.003 to 0.01	0.26

Abbreviations: CI, confidence interval; ISS, Injury Severity Score

and a rock.[3] In a marine disaster where a high-speed passenger ship collided with a whale in South Korea, the field triage and patient transportation process lasted for 3 hours after the collision.[4]

The implication of such a considerable time lag is that most receiving EDs should have adequate time in mobilizing extra staff and resources to cope with the surge in demand, provided that information about the number of victims and their severity of injury is clear soon after the accident. Given the even longer time intervals between the accident and X-ray examination, hospital admission, ICU admission, and surgical operations; receiving hospitals should have enough time to increase capacity in key downstream clinical departments to avoid creating bottlenecks after ED arrival of the victims.

In Hong Kong, all public EDs are under the administration of the Hospital Authority. As a result of this, in the event of an MCI, patient transfer to different public hospitals is coordinated by the Hospital Authority's Head Office Major Incident Control Centre (MICC). On request by the scene commander, an ED in the catchment area of a particular MCI can dispatch an emergency physician to play the role of medical control officer to coordinate patient transfer to different public EDs from the scene. In some MCIs, emergency medical teams are dispatched to provide field triage and emergency treatment to casualties.[9] In most scenarios in this study, field triage and patient diversion to different hospitals were performed only when victims reached the gathering point on the shore, not on the involved vessels. Earlier communication between the ferry crew, rescue agencies, MICC, and the receiving hospitals, while the damaged vessel is returning to the pier or the evacuation is still in progress, would help the receiving hospitals to mobilize personnel and resources earlier.

Understandably, assessment of passenger condition is not the only consideration immediately after ferry collision. There are many competing priorities on board, such as assessment of water ingress, possibility of abandoning ship, and risk of oil leak and environmental contamination, as well as notification to the authorities, communication with other affected vessels, etc. In order to quickly assess and communicate passenger condition, the use of a simple field triage algorithm modified for laypersons can be considered. The Simple Triage and Rapid Treatment (START) algorithm is a field triage tool commonly used by rescue agencies and emergency medical teams for disaster in Hong Kong and in many other countries. The START triage ratings correlate well with the ISS.[23] The algorithm can also be simplified further for quick application by non-medical personnel with little training.[24] Instead of applying the full algorithm, ferry crew can be trained to quickly identify the 'walking wounded,' i.e., those with minor injuries, and count the rest of the passengers as having more serious injuries. The quickest way to identify the 'walking wounded' is to ask the victims whether they can walk. This does not require much medical training of the ferry crew but can provide invaluable information on the scale of accidents to rescue agencies and receiving hospitals using a common language. This algorithm can be included in the

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emergency response protocol onboard and should be tested and refined in simulation exercise before adoption.

The results of this study also showed that the dual-wave phenomenon was not present in the MCIs that involved HSPFs. Victims with moderate or major trauma (ISS ≥ 9) had a significantly shorter median time interval between accident and ED registration as compared to those with minor injuries. Even after adjustment for circumstantial factors, multivariable linear regression showed that these patients arrived 0.37 hours (i.e. 22.2 minutes) earlier than victims with minor injury. These findings suggest that the pre-hospital triage system was effective in prioritizing care to victims with more serious injuries. The absence of the dual-wave phenomenon in HSPF accidents can also be explained by the fact that none of the victims required prolonged extrication from the damaged vessels, and self-transportation from the accident site, which would otherwise have resulted in earlier presentation of victims of mild injuries, was not seen in HSPF accidents because almost all victims were brought to the shore triage point by rescue agencies. However, it is noteworthy that a few victims with moderate or major trauma continued to arrive at EDs up to 6 hours after the accidents.

Multivariable linear regression showed that the sinking of a vessel in an accident and the night-time occurrence of accidents were associated with 0.98 hours (i.e. 58.8 minutes) and 0.67 hours (i.e. 40.2 minutes) delay in ED arrival, respectively. Both factors increase the difficulty of rescue, and it is not surprising to see such delays. Interestingly, despite a significant association, each 1 km increase in the linear distance between the accident, and receiving ED was only associated with 0.08 hours (i.e. 4.8 minutes) of delay in ED arrival, indicating circumstantial factors are more important than physical distance in affecting the time interval between accident and ED arrival. It is important to note that the regression model showed that victims who were evacuated by emergency service vessels on the spot of the accident arrived at the ED 0.92 hours earlier. This can be explained by the fact that in accidents where the damaged ferries returned to the pier under their own power after collision (thus obviating the need for vessel evacuation and transportation by emergency service vessels), they travelled at a very slow speed, which prolonged the time interval between the accident, and ED arrival. It is important to also note that vessel evacuation and transportation by emergency service vessels on the spot of the accident in the sea carries significant risks. Its association with a shorter time interval should not be viewed as a simple solution to shorten the time delay. Other circumferential factors, such as the conditions of the damaged vessel, weather, and sea conditions, should also be factored in when making such a decision. Selective evacuation of the mostly seriously injured victims on the spot is a potential strategy to balance the benefit of shorter delay and evacuation risks.

Limitations

This study had a few limitations. First, information about the pre-hospital phase of the rescue, such as the field triage category of individual victims, was not accessible. These factors might have influenced the time pattern of presentation. Second, the actual distance between the accident site and receiving hospitals was not traceable. We could only estimate the distance based on GPS coordinates and we believe the calculated distance is the best available surrogate for the actual distance. Third, the factors in the multi-variable linear regression model could only explain 30% of the variance in the time interval between accident and ED registration. Many pre-hospital factors, such as the accident site to the port time, waiting time for ground or air-transport at the port, and ground or air transport time of individual victims were not accessible. Fourth, the findings were derived from MCIs that involved HSPFs in Hong Kong waters, with collisions as the major form of the accidents. They might not be generalizable to other places due to regional variations in maritime traffic density, regulation of marine vessels, and disaster response systems. The findings might also not be applicable to other forms of HSPF accidents, such as fire and grounding.

Despite these limitations, this study provides useful real-world data for disaster planning of surge capacity in response to HSPF MCI in the urban setting. To make the response plan more adaptive to different scenarios, further studies comparing different forms of HSPF accidents and MCIs that involve HSPF versus other types of passenger vessels are warranted. Different time points along the chain of emergency response before the hospital arrival of individual victims should also be captured in future studies in order to identify potential targets to shorten the time delay. Calculation of distance between the accidents and receiving hospitals would best be based on data from the nautical chart of the damaged and rescued vessels.

Conclusions

Given the time lag of 2 to 3 hours between the accident and the arrival of victims, EDs should have enough time to mobilize extra resources to cope with the anticipated surge in demand. The dual-wave phenomenon was not present in HSPF accidents, but ED may need to reserve resources for more seriously injured victims who present later during rescue. Our data showed that an ISS ≥ 9 and evacuation by emergency service vessels were associated with a shorter delay in ED arrival, whereas ship sinking, accident at night-time, and a longer linear distance between the accident, and receiving ED were associated with a longer delay. Early communication between the ferry crew, rescue agencies, and receiving EDs is the key to ensure early mobilization and well-timed response to seriously injured victims arriving at different time points after the accident.

Abbreviations

AIS	Abbreviated Injury Scale
AEIS	Accident & Emergency Information System
CI	Confidence Interval
ED	Emergency Department
EMDM Academy	Academy for Emergency Management and Disaster Medicine
GPS	Global Positioning System
HSPF	High-speed Passenger Ferry
ICU	Intensive Care Unit
IQR	Interquartile Range
ISS	Injury Severity Score
MCI	Mass Casualty Incident
MICC	Major Incident Control Centre
N/A	Not Applicable
START Algorithm	Simple Triage and Rapid Treatment Algorithm

Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/dmp.2024.90.

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Authors contribution. RPKL conceived and designed the study and developed the method. WRTM, WKW, CACK, and TTC, as well as CTK, CPPY, KFHF, and LCS, retrieved medical records, performed chart review, and collected data. YSM also contributed. WRTM performed trauma coding. RPKL and EHYL analyzed and interpreted the data. EHYL, CVK and CL plotted the figures. RPKL drafted the article. All authors contributed substantially to its revision and provided final approval. PRKL takes the responsibility for the paper.

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