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Review Article

Motorboat propeller-related head injuries: A systematic literature review with a case illustration

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ABSTRACT

Background: Propeller-related injuries from motorboats are a major cause of injury in recreational water activities including severe and multiple lacerations that can promote scarring, blood loss, traumatic, or surgical amputations. The real incidence of these accidents is still unclear. The authors here present a systematic review of the literature, focusing on head injury, and related recommendations for its evaluation and management, also reporting a case of a female patient injured by a motorboat propeller.

Methods: A systematic literature review was conducted according to the preferred reporting items for systematic reviews and meta-analyses statement, with no limits in terms of publication date. The following Mesh and free text terms were identified: "motorboat and propeller and injuries" (107 results).

Results: A total of 12 papers were included in this systematic review. Only few case reports describing traumatic brain injury (TBI) have been documented. Out of a total of 90 cases analyzed, only five cases with TBI were reported. The authors also reported a case of a 12-year-old female, that during a boat trip, reported a severe polytrauma with concussive head trauma from a penetrating left fronto-temporo-parietal lesion, left mammary gland trauma and fracture of the left hand from falling into the water and impact with a motorboat propeller. She underwent an urgent left fronto-temporo-parietal decompressive craniectomy and then surgery with a multidisciplinary team. At the end of the surgical procedure, the patient was transferred to the pediatric intensive care unit. She was discharged on postoperative day 15. The patient was able to walk without assistance, with mild right hemiparesis and persistence of aphasia nominum.

Conclusion: Motorboat propeller injuries can result in extensive damage to soft tissue and bones with severe functional disability, amputations, and high mortality. There are still no recommendations and protocols for the management of motorboat propeller related injuries. Although there are several potential solutions that aim to prevent or ease motorboat-propeller injuries, there are still lack of consistent regulations.

Keywords: Hemicraniectomy, Infections, Motorboat, Propeller, Traumatic brain injury

INTRODUCTION

Propeller-related injuries associated to falls, drowning and burns, can occur during boating recreational activities. Propeller injuries from motorboats are a major cause of injury in recreational water activities including deep, multiple, and parallel lacerations that can promote scarring, blood loss, and traumatic or surgical amputations.[1,4,5,7,9]

The real incidence of these accidents is still unclear. During a period from 2009 to 2013, there were 915 reported cases of propeller injuries, with 129 deaths (14.1%) in the USA and 2.6% related to propeller strikes, with overall fatality rate of 15–23%, and a similar rate of major amputations.[6] In 2019, the USA Coast Guard documented 4.168 recreational boating accidents, which included 2.559 injuries and 613 deaths.[2] Furthermore, injuries tend to occur during the summer period, with a higher frequency between 11 and 20 years of age with an overall fatality rate of 10–17%.[5,8,10,11]

Head trauma has been reported as the most common cause of death with up to 40% of deaths with a fatality rate from 1976 to 1990 of 0.3–1.3%.[1]

Furthermore, serious late-onset complications such as wound infection, near drowning injuries, and hypothermia can occur, often with unusual bacteria that may not be detected by routine blood culture sampling.[2,3]

Herein, the authors present a case of a female patient injured by a motorboat propeller with a review of the literature, focusing on head injury, and related recommendations for its evaluation and management.

MATERIALS AND METHODS

A systematic literature review was conducted according to the preferred reporting items for systematic reviews and meta-analyses statement, with no limits in terms of publication date [Figure 1]. Recorded studies were exported to Mendeley software. Only articles in English language were included in the study. All the duplicates were removed and a manual search was also performed to identify eventual additional studies of the reference sections. Two reviewers (G.S. and M.P.S.) independently screened the titles, abstracts, and full manuscripts, then the results were combined and analyzed. The following Mesh and free text terms were identified: "motorboat and propeller and injuries" (107 results).

Elegibility criteria

The articles were selected according to the following inclusion criteria:

- Full article in English
- Human subjects
- Clinical studies (case reports, case series, and retrospective studies)
- Studies focusing on head trauma
- Studies focusing on severe speedboat-related injuries.

Exclusion criteria

The following criteria were excluded from the study:

- Articles not in English
- Meta-analysis.

Data extraction

The available data included authors, year, study design, number of patients, sex, age, injuries, injury type, eventual surgical amputation, and death.

RESULTS

A total of 107 published studies were identified through PubMed and Google Scholar databases and additional reference list searches. After removing duplicates, the papers screened were $n = 96$. Based on the titles and abstracts, the authors then excluded $n = 80$ articles. The titles and abstracts of the articles identified during the literature search were reviewed to check if they fulfilled the following inclusion criteria: full article in English, human subjects, clinical studies (case reports, case series, and retrospective studies), and studies focusing on head trauma and severe speedboat-related injuries. The articles that remained were assessed in full against exclusion criteria: articles not in English and meta-analysis. Three articles were not retrieved due to the unavailability of the full text, no article was excluded because not in English language. Then, another one paper was excluded due to incompatibility with our eligibility criteria. Finally, a total of 12 papers were included in this systematic review [Table 1]. The described flowchart is reported in Figure 1. According to our literature review, only few case reports describing traumatic brain injury (TBI) have been documented. Out of a total of 90 cases analyzed, only five cases with TBI were reported.

Case description

A 12-year-old female, during a boat trip, reported a severe polytrauma characterized by concussive head trauma from a penetrating left fronto-temporo-parietal lesion, lacerated-contusive trauma of the chest wall, left mammary gland trauma (multiple contused lacerated wounds with loss of substance and necrotic areas), and fracture of the left hand from falling into the water and impact with a motorboat propeller [Figures 2a and b].

The patient sedated and intubated, was transferred to our institution. She immediately performed a brain computed tomography (CT) scan that showed multiple left fronto-temporo-parietal skull fractures and contusive-hemorrhagic lesions [Figures 3a and b].

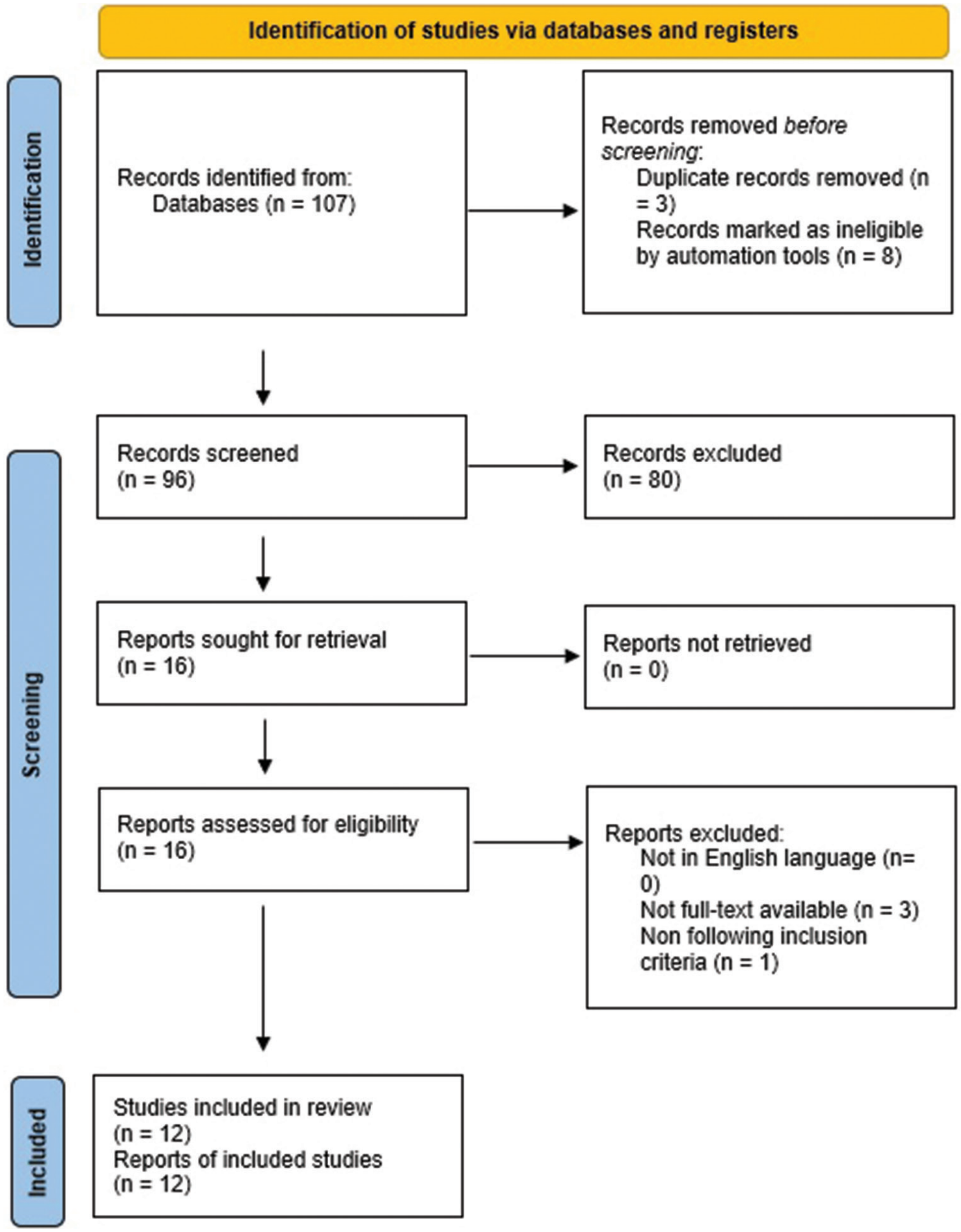

Figure 1: Preferred reporting items for systematic reviews and meta-analyses flow diagram reports the decision algorithm for the selection of the studies of the systematic review. n is for number.

She underwent an urgent left fronto-temporo-parietal decompressive craniectomy. At the end of the surgical procedure, the patient was transferred to the pediatric intensive care unit (ICU).

The following day, she underwent surgery with a multidisciplinary team (breast and orthopedic surgery) consisting of curettage and remodeling of the left breast, revision of the multiple lacerated contusive wounds of the left axillary cavity and left wrist with inspection, reduction, and fixation with Kirschner wires of the 1st and 2nd finger fractures.

During hospitalization in pediatric ICU, she underwent seriated head CT scan and brain magnetic resonance imaging which documented diffuse cerebral damage in the left fronto-temporo-parietal lobe.

After surgery, she presented aphasia nominum and right hemiparesis. Nonetheless, during hospitalization, the patient showed a progressive neurological improvement, recovering also cognitive functions.

She was discharged on postoperative day 15. The patient was able to walk without assistance, with mild right hemiparesis

Table 1: Demographics and injuries of current literature data.

Author	*n*	Gender		Mean age	Injuries	Amputation	Death
		M	F				
Janda *et al.*, 1998[7]	13	9	4	26	Lacerations, broken bones	NO	3
Dhall *et al.*, 2008[1]	1	1	/	4	Head injury	NO	NO
Garg *et al.*, 2011[3]	5	4	1	33,6	Lacerations, open fracture of the ulna, fracture of the radius, extra-articular comminuted fracture of the scapula, fractures of ribs 9–12, dislocation of the patella with rupture of the cruciate and medial collateral ligaments, comminuted fracture of the patella, open comminuted fracture of the femur	Subtotal amputation just below the knee	NO
Hargarten *et al.*, 1994[4]	14	14	/	18.3	Multiple lacerations, fractures of the iliac crest and sacroiliac, multiple lacerations of the abdomen and upper extremity, fractures of the omerus, ulna and radius	Amputation at the elbow, near-complete amputation of the lower extremity	3
Hoexum *et al.*, 2017[5]	4	3	1	23,5	Laceration, open fracture of the calcaneus, fractures of the talus, navicular, several avulsion fractures, comminuted fractures of the talus, lateral cuneiform, 2nd and 3rd metatarsal bones and of his 5th digit, avulsion fracture of the attachment of the Achilles tendon to the calcaneus, injury to the peroneal tendon	Traumatic amputation of the malleolus including the deltoid ligament, subtotal traumatic amputation through the distal tibia	NO
Ihama *et al.*, 2009[6]	3	2	1	45	Multiple lacerations, fractures of the ribs, scapula, humerus, femur, pelvis, lower limb, head injury	Lower limb	3
Keijzer *et al.*, 2013[8]	15	6	9	11	Femur, tibia, fibula fracture. Lung contusion, splenic rupture, scapula, rib fracture, vertebral fracture, rib fracture, lung contusion, pneumothorax, head injury, ileum fracture, open abdomen, small bowel injury, wound arm, acetabulum fracture, kidney rupture, iliac wing	Lower leg amputation, near ankle amputation injury	NO
Mann, 1976[9]	9	5	4	26,7	Multiple laceration, open comminuted fractures of the tibia, femur, open fracture of the ulna, dislocation of the distal radioulnar joint, open fracture involving the knee joint, fracture of the interphalangeal joint	Above knee amputation, bilateral above knee amputation, above elbow amputation	3
Mendez-Fernandez, 1998[10]	9	6	3	27,3	Multiple laceration, penetrating injuries, comminuted fractures of the metacarpals	Amputation above the knee	1
Price *et al.*, 2014[11]	13	11	2	32	Multiple laceration	Proximal transhumeral amputation, thumb amputation, above knee amputations	NO
Semeraro *et al.*, 2012[12]	3	3	-	-	Multiple laceration, comminuted fractures of the radius and ulna, comminuted fractures of the distal tibia and fibula, head fracture, ribs fractured, T4, T8 vertebral fractures	-	3
Sladden *et al.*, 2014[13]	1	1	-	44	Chest laceration	-	-

n is for number of patients, M: Male, F: Female.

and persistence of aphasia nominum. She was therefore discharged with a program of hospitalization to another country (England) for neurorehabilitation and cranioplasty planning.

DISCUSSION

Every year the water recreation demand is increasing, and that clearly increase the incidence of boating-related injuries.[2]

Figure 2: Preoperative images after basic life support procedures showing concussive head trauma from a penetrating left fronto-temporo-parietal lesion (a) lacerated-contusive trauma of the chest wall, left mammary gland trauma (multiple contused lacerated wounds with loss of substance and necrotic areas) and fracture of the left hand from falling into the water and impact with a motorboat propeller (b).

Propeller strikes are often an indirect consequence of an evolving in progress accident and the injuries are sustained by the impact of the moving propeller blades.[6,11,14]

Usually, the first event can be represented by: man overboard, collision, running aground, capsizing, sudden acceleration or deceleration, mechanical failure, red wave hit, and high wake hit.[14] Indeed, the propulsion of a boat is obtained by the rotational movement of the propellers, made of radiating and helicoidal blades, like a screw, that transform rotational power into thrust.[6,11,14]

Water sports, such as skiing and wakeboarding, pose the highest risk of propeller injuries, mainly due to the repeated close interaction with the moving motorboat.[2] Approximately 20% of propeller injuries occur at speeds <10 mph.[11] A three-bladed propeller rotating at 3200 rpm and with a blade length of 13 inches (33.2 cm) can cut a person from head to toe in less than a tenth of a second.[6,9] Because of their severity, propeller injures can be compared with battlefield injuries.[10]

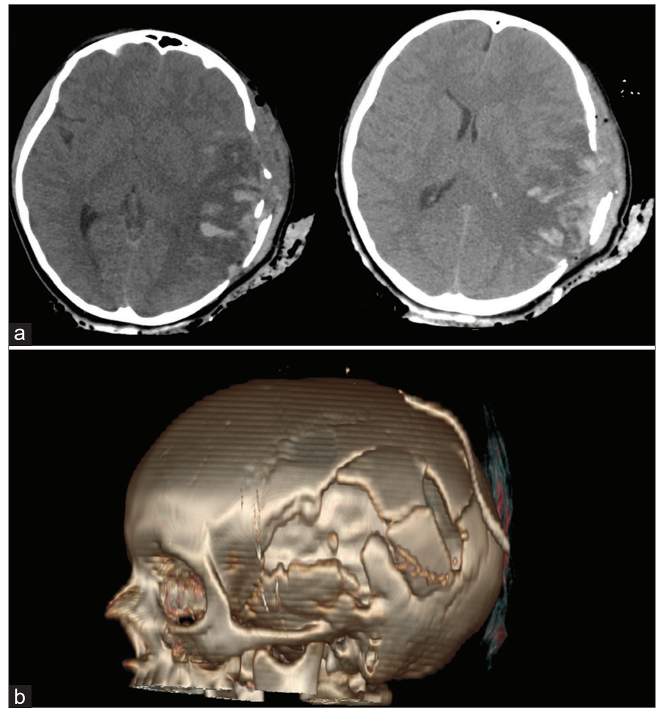

Figure 3: Preoperative brain computed tomography scan axial images showed multiple left fronto-temporo-parietal skull fractures and contusive-hemorrhagic lesions (a) and 3D reconstruction of the multiple skull fractures (b).

Wounds include repeated, deep, and sharp parallel lacerations with potential loss of bone and soft-tissue structures, more frequently involving lower limbs.[1,4,5,7,12]

In the paper described by Ihama *et al*., the autopsy reports two patients who died after TBI. In the first case, the patient died after a brain injury due to the chop wound on the head that exposed the cranial vault and the left hemisphere of the brain was missing. In the second case, the patient died after a brain injury due to a severe deep chop wound on the forehead with a skull fracture that exposed the cranial vault and lacerated the frontal lobes bilaterally, slight subarachnoid hemorrhage, and coagulated hematoma in both cerebral lateral ventricles.[6]

Dhall *et al*. reported a pediatric case of TBI characterized by intracerebral hemorrhage and edema that underwent a decompressive left-sided hemicraniectomy, evacuation of hemorrhage, and wound debridement.[1] Finally, Keijzer *et al*. described two cases out of a total of 15 patients analyzed, of which one closed head injury and one case of open skull fracture.[8]

The management protocols for these wounds are multidisciplinary and should evaluate several factors such as the size and location of the wounds, the associated lesions, and the level of contamination.[5,11,13]

Diagnostic imaging is essential to evaluate a patient after a traumatic injury. In stable patients, the use of abdominal and pelvis CT scans with contrast is indicated for the evaluation of gynecological lesions, while CT scans with rectal contrast and rigid proctoscopy for the evaluation of colorectal lesions. However, it is important to consider the instability of the trauma patient and evaluate the appropriateness of laparoscopy.[2]

The first surgical step involves extensive debridement, exploration, and rinsing of the wound in the operating room as soon as possible in highly contaminated open fractures or within 12 h in high-energy exposed fractures that are not highly contaminated.[5] In particular, for larger and deeper wounds, lavage is preferably performed in the operating room.[2] According to Mann wound closure is preceded by multiple debridement every 48 h in the operating room until closure or grafting.[9] Reduction and fixation of bone lesions can be applied for initial management and stabilization of bone lesions. Primary reconstruction of neurovascular structures is rarely possible. Early wound coverage reduces the rate of infection. If primary closure is not possible, soft-tissue reconstruction should be performed by local transposition or free flap reconstruction, preferably within 72 h.[5,9]

The propeller wounds become infested with bacteria from the aquatic environment.[5] As the propeller creates a laceration, water on the high-pressure side is forced into the wound creating a cavity like jet injection injuries. Organisms can be pushed deep into bruised or nonvascular damaged tissue.[11] The number of bacteria present in the water is higher during the summer period. According to Hoexum *et al*., the empirical antibiotic regimen should be based on the type of aquatic environment.[5] Early freshwater infections are caused by typical aquatic bacteria such as *Aeromonas* spp., *Pseudomonas* spp. and a variety of other gram-negatives (*Escherichia coli*, *Klebsiella* spp., *Shewanella* spp., and *Aeromonas* hydrophila) as well as *Staphylococcus aureus* and *Streptococcus pyogenes* (Group A).[5,9,11]

Therefore, antibiotic prophylaxis was recommended for 5–7 days depending on the severity of the trauma and the extent of the soft-tissue injury, with a combination of a penicillin with anti-pseudomonas/Aeromonas (e.g., piperacillin) with an aminoglycoside (e.g., gentamicin or tobramycin) or a third-generation cephalosporin with anti-pseudomonas activity (ceftazidime) or a fluoroquinolone (e.g., ciprofloxacin). Optionally, a third-generation cephalosporin with anti-pseudomonas activity (ceftazidime) or a fluoroquinolone (e.g., ciprofloxacin) is given for penicillin-allergic patients. For saltwater injuries, however, an aminoglycoside with the addition of doxycycline is recommended to cover the infection caused by *Vibrio* spp., which can cause early infections associated with saltwater environments.[2,5,11] A tetanus booster is recommended if the last immunization was more than 10 years ago.[5]

Necrotizing fasciitis is the most severe consequence of wound that were exposed to the water.[2] Because of the difficulties in diagnosing delayed infections in trauma patients, more frequent follow-up is reasonable.[11]

The current public health measures to prevent traumatic injuries in marine environments include the use of life jackets, the installation of engine cutoff switches (ECOS), and the prohibition of hazardous activities. The life jacket can not only save life, but also preserve body heat and clarity of mind by raising the head and chest above the water surface, as well as make it easier to locate and rescue an injured person.[2]

However, due to poor legislation mandating their use, most swimmers and boaters do not regularly wear a life jacket during water activities. Furthermore, it has been noted that one of the reasons mariners do not wear life jackets is out of concern that it may make them appear inexperienced or unable to swim. Another safety device is the use of ECOS on boats or on water scooters. It is a physical or wireless connections, that is connected to the boat operator and that automatically shut off the engine if the connection is even temporarily interrupted. However, the use of such a device is completely circumvented because of the lack of sufficient consideration and explanation on how to use it properly.[2]

CONCLUSION

Motorboat propeller injuries can result in extensive damage to soft tissue and bones with severe functional disability, amputation, and even exitus. To date, there are still no recommendations and protocols for the management of motorboat propeller-related injuries.

Although there are several potential solutions that aim to prevent or ease motorboat-propeller injuries, there are still lack of consistent regulations.

Enhancing safety measures through education and a strong law enforcement support, in conjunction with the development of effective safety devices, has the potential to decrease the incidence of these injuries.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Dhall SS, Lin FJ, Tumialan LM, Mapstone TB. Significant neurologic recovery following a catastrophic open head injury from a motorboat propeller: Case illustration. J Trauma 2008;65:249-50.
2. Ehrhardt JD, Newsome K, Das S, McKenney M, Elkbuli A. Evaluation and management of watercraft-related injuries for acute care surgeons: Towards improving care and implementing effective public health prevention policies. Ann Surg 2022;3:e149.
3. Garg H, Twerenbold R, Zellweger R. Propeller and jet-ski injuries during Christmas and New Year in Western Australia. Med J Aust 2011;195:704-5.
4. Hargarten SW, Karlson T, Vernick JS, Aprahamian C. Motorboat propeller injuries in Wisconsin: Enumeration and prevention. J Trauma 1994;37:187-90.
5. Hoexum F, van Delft EA, van Couwelaar G, van der Steeg AF, Ang CW, Geeraedts LG, *et al*. Motorboat propeller injuries: A case series and review of the literature. Trauma Mon 2017;22: e40270.
6. Ihama Y, Ninomiya K, Noguchi M, Fuke C, Miyazaki T. Fatal propeller injuries: Three autopsy case reports. J Forensic Leg Med 2009;16:420-3.
7. Janda S, Perez C, Hospital B, Rast AM, Cherry D, Hunteman J, *et al*. From the Centers for Disease Control and Prevention Leads from the Morbidity and Mortality Weekly Report. Vol. 47. Atlanta, GA: CDC; 1998. p. 47.
8. Keijzer R, Smith GF, Georgeson KE, Muensterer OJ. Watercraft and watersport injuries in children: Trauma mechanisms and proposed prevention strategies. J Pediatr Surg 2013;48:1757-61.
9. Mann RJ. Propeller injuries. South Med J 1976;69:567-9.
10. Mendez-Fernandez MA. Motorboat propeller injuries. Ann Plast Surg 1998;41:113-8.
11. Price CT, Muszynski MJ, Zielinski JA, Stewart C. Motorboat propeller injuries: Report of thirteen cases with review of mechanism of injury and bacterial considerations. J Trauma Treat 2014;4:267.
12. Semeraro D, Passalacqua NV, Symes S, Gilson T. Patterns of trauma induced by motorboat and ferry propellers as illustrated by three known cases from Rhode Island. J Forensic Sci 2012;57:1625-9.
13. Sladden D, Casha AR, Manche' A. Chest wall reconstruction following a speedboat propeller injury. Malta Med J 2014;26:48-51.
14. Typical Propeller Accident Scenarios. Propeller Safety. Available from: http://www.propellersafety.com/propeller-accident-scenarios [Last accessed on 2023 Feb 28].

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