# Clinical features of 27 shark attack cases on La Réunion Island

**Richard Ballas, MD, Ghislain Saetta, Charline Peuchot, Philippe Elkienbaum, MD,** *and* **Emmanuelle Poinsot, MD**, *Saint Paul, Ile de La Réunion, France*

**BACKGROUND:** Between January 2000 and September 2016, there have been 27 documented shark attacks on La Réunion Island. The insular nature of La Réunion has allowed us to perform an extensive survey of these attacks. The objective was to describe the clinical features of these shark attacks, as only case reports have been published up to now.

**METHODS:** This was a retrospective observational study of the 27 cases of nonprovoked shark attacks that have occurred between January 2000 and September 2016. Post-humate predation, provoked attacks, and isolated attack on devices were excluded. All bone and vascular injuries were documented in the 21 remaining cases. Prehospital tourniquet use was specifically recorded.

**RESULTS:** Among the 21 victims, eight died (38%) despite rapid use of resuscitation techniques in five cases when it was feasible; these techniques were not needed in the survivors. Thirteen patients were immediately treated in the operating room. Amputation or disarticulation occurred 13 times in 10 victims, five of whom died. Twelve injuries to major vascular structures were found in 11 victims, six of which died. A prehospital tourniquet was applied in four of the five surviving victims who had injuries to major vascular structures (including one victim with major humeral and femoral artery damage) and in one victim who died (the very proximal wound was not controlled).

**CONCLUSION:** Our study found that quickly applying a tourniquet to the injured limb(s) contributes to the victim's survival. Disarticulation is a particular feature of shark attacks. The number and severity of shark attacks at La Réunion Island are worse than in the rest of the world. (*J Trauma Acute Care Surg.* 2017;82: 952–955. 

**LEVEL OF EVIDENCE:** Epidemiological, level V.

**KEY WORDS:** Shark attack; acute care; La Réunion Island; trauma surgery; tourniquet.

Between 2000 and 2016, an average of 87 nonprovoked shark attacks occur each year throughout the world, leading to 8.82 deaths per year on average.[1,2] During this period, there was an average of 3.6 shark attack cases per year in France, with 0.9 deaths per year on average. All of these attacks occurred in France's overseas departments and territories: 1 in Wallis-and-Futuna, 11 in French Polynesia, 20 in New Caledonia, and 27 in La Réunion Island.

There are no large clinical studies on shark attacks in the literature. We have only found clinical case reports.[3,4] Forensic medicine studies have put forward hypotheses on the circumstances of these incidents based on accounts from local authorities, witnesses, and victims.[5,6] However, it is not always possible to identify the cause of death based on a study of human remains when posthumous predation occurred or the attack was fatal.[5] Clinical data surrounding the care, treatment, or intraoperative observations are not always available in that type of study, which is another limitation. Other studies have extracted the details of shark attacks from databases.[2,7–9] The International Shark Attack File compiles all of the shark attacks throughout the world;[1] there are also country-specific databases such as the KwaZulu-Natal Sharks Board in South Africa[10] and the Australian Shark Attack File.[11] These databases are populated using a questionnaire that is sent to witnesses to collect information about the attack.[11,12] However, this questionnaire does not capture data from the medical records. The injury descriptions are not exhaustive, and the survey of the victims is often incomplete.[13]

The shark attack rate is higher in La Réunion Island than in any other geographic area in the world. Since 2000, there have been 3.11 shark attacks per 100,000 inhabitants; the island's population was 835,103 in 2013.[14] This is 15 times higher than in South Africa, 14 times higher than in the United States, and 3 times higher than in Australia (which has 35,000 km of coast line and 1,680,000 surfers). Given the estimated 500 participants in water-based activities[14] and the 40 km of coast line suitable for swimming at La Réunion Island, this shark attack rate is unusually high relative to the rest of the world.[11] Because of the geography of La Réunion Island, shark attack victims are treated by a limited number of hospitals and orthopedic surgeons.

The purpose of our study was to describe the clinical characteristics of the injuries induced by shark attacks and to explore which factors contribute to their severity and the victim's death.

## METHODS

This was a retrospective observational study of shark attacks on La Réunion Island. All the victims of nonprovoked shark attacks on the island between January 2000 and September 2016 were included. This was a continuous case series. A nonprovoked

Submitted: November 7, 2016, Revised: January 7, 2017, Accepted: January 24, 2017, Published online: February 28, 2017.

From the Service de chirurgie orthopédique (R.B., C.P.), Centre Hospitalier Gabriel Martin, Saint Paul; Laboratoire IRISSE (EA4075) (R.B.), UFR SHE, Université de La Réunion, Le Tampon; Seprodom S.A.R.L. (G.S.), La Possession; Service de chirurgie orthopédique (P.E.), CHU Réunion-Site Sud Réunion, Saint-Pierre Cedex; and Service de chirurgie orthopédique infantile (E.P.), CHU Réunion-Site Nord, Ile de La Réunion, France.

Address for reprints: Richard Ballas, MD, Service de chirurgie orthopédique, Centre Hospitalier Gabriel Martin, 38 rue Labourdonnais, 97460 Saint Paul, Ile de La Réunion, France; Laboratoire IRISSE (EA4075), UFR SHE, Université de La Réunion, Le Tampon, Ile de La Réunion, France; email: richardballas@yahoo.fr.

DOI: 10.1097/TA.0000000000001399

shark attack was defined as aggressive physical contact between one or multiple sharks and a human in a shark's natural habitat, without human provocation,[15] that results in physical injuries.

Provoked attacks were excluded. A provoked attack was defined as one in which a human initiates physical contact with a shark.[11] The single case of posthumous predation was excluded.[16] Five attacks on objects in which the victims were unharmed were excluded: two surfboards, one bodyboard, one Hawaiian outrigger, and one waveski.[17]

The data were taken from the medical records of patients admitted to the *Centre Hospitalier Gabriel Martin de Saint-Paul*, the *Centre Hospitalier Universitaire de La Réunion*, and the *Groupe Hospitalier Est Réunion*. These three hospital facilities are the only trauma centers on La Réunion Island. The physicians present at the time of the attack or who provided medical care were questioned to collect data related to victims who died at the site of the attack before they could be transported to a hospital (five cases).

We also collected general data about the victims, circumstances of the attack, injuries observed during the physical examination, and information about the treatment provided. Some of the victims had multiple injuries. The most serious injury to each limb was retained. The injuries were classified as suprafascial (abrasion/contusion, skin/soft tissues) or subfascial (tendon/muscle/bone, major vascular structures). Proximal artery damage (carotid, humeral, femoral) was recorded, as were amputations and disarticulations.

The injuries were classified according to the score and injury level in the Shark-Induced Trauma (SIT) Scale.[7] This score includes a measurement of the initial blood pressure, the location of the injury, the depth of the injury, the impairment due to the injury, and the complexity of the required treatment. The arithmetic sum of these scores defined the severity of the injuries on a five-level grading system. We also used the three-level prognostic score of the Durban classification described by Davies and Campbell[9] to establish a prognosis based on the main vascular structures damaged. If the victim's body was not found, we assumed that a major vessel in the trunk region had been damaged. The use of a tourniquet at the attack site was documented. Standard descriptive statistics were calculated.

## RESULTS

Of 27 nonprovoked attacks, 21 victims (19 men and 2 women) were included in this case series. The average age was 29.8 ± 11.4 years (13–51 years). At the time of the attack, 18 victims (86%) were surfing or bodyboarding, and 3 were swimming or underwater hunting. Eight (38%) died. Accidents involving the bulldog shark (*Carcharhinus leucas*) were the most frequent, 11 cases having been documented and 6 of which were fatal. The tiger sharks (*Galeocerdo cuvier*) were implicated in four attacks, one of which was fatal. The sharks were not identified in six cases. Attacks occurred 2 times before 9 AM, 7 times between noon and 3 PM, and 12 times after 4 PM. Seventeen attacks occurred during austral winter. Chest compressions were carried out in five victims (none survived), and open-chest cardiac massage was done in one of these victims in the operating room. Resuscitation maneuvers were not relevant in the other three cases (body not found, severing at the trunk or long delay before the body could be recovered). Dead or brain-dead status was presumed immediately in seven of the eight cases. In the other case, the patient died within 24 hours in the intensive care unit after surgical treatment because of disseminated intravascular coagulation secondary to hemorrhagic shock. This patient was in cardiac arrest at the attack site for an estimated 30 minutes.

The victims were treated in the emergency room in 2 cases and in the operating room in 13 cases by an orthopedic surgeon, who works with a vascular surgeon in four cases and a third surgeon (urologist) in one case (scrotal wound).

A single site was injured in nine cases, two sites in five cases, and three or more sites in seven cases. The injuries are described in Table 1. Disarticulation (seven injuries in six patients) corresponded to the presence of bare bone in a limb segment stripped of its soft tissues, associated with distal disarticulation (photo 1). A trunk injury (thorax, abdomen, or pelvis) was present in five victims, all of whom died; two had fatal intracavity organ injuries. The scores in SIT Scale and the Durban classification were associated to death (Table 2). Among the 13 surviving victims, five had injuries to major vascular structures, including two injuries in the same patient. All eight of the victims who died had injuries to major vascular structures; six had isolated major vascular lesions in a limb.

**TABLE 1.** Description of Victims' Injuries

| | Total, n = 21 | Surviving, n =13 | Died, n = 8 |
|---|---|---|---|
| Upper limb | 4 | 3 | 1 |
| Lower limb | 8 | 6 | 2 |
| Upper and lower limb | 9 | 4 | 5 |
| Arm | 3 | 2 | 1 |
| Forearm | 6 | 3 | 3 |
| Hand | 4 | | |
| Thigh | 9 | 4 | 5 |
| Lower leg | 8 (n = 7) | 6 | 2 (n = 1) |
| Foot | 2 | 2 | |
| Trunk | 5 | 0 | 5 |
| Abrasion/contusion | 0 | | |
| Skin/soft issues | 3 | | |
| Tendon/muscle/bone | 6 | | |
| Major vasculature of limbs | 12 (n = 11)* | 6 (n = 5)* | 6 (n = 6) |
| Humeral | 3 | 2 | 1 |
| Femoral | 9 | 4 | 5 |
| Prehospital tourniquet use | 4 | 4 | 0 |
| Amputation/disarticulation | 13 (n = 10)** | 7 (n = 5) | 6 (n = 5) |
| Arm | 2 | 1 | 1 |
| Forearm | 2 | 0 | 2 |
| Wrist | 2 | 1 | 1† |
| (Fingers) | (1) | (1) | |
| Thigh | 2 | 1 | 1 |
| Knee | 2 | 2 | 0 |
| Ankle | 3 | 2 | 1 |

*One surviving patient had two major vascular injuries: humeral and femoral.

**One surviving patient had an arm amputation and ankle disarticulation; one surviving patient had a wrist and ankle disarticulation; one patient who died had a forearm and thigh amputation.

†Associated with a major vascular injury to the thigh in one patient.

In cases of multiple injuries, only the most severe injury in each limb is listed.

**TABLE 2.** The SIT Scale and the Grade in the Durban Classification

| | Total, n = 21 | Surviving, n =13 | Died, n = 8 |
|---|---|---|---|
| SIT level | | | |
| Level 5 | 8 | 1 | 7 |
| Level 4 | 5 | 4 | 1 |
| Level 3 | 1 | 1 | 0 |
| Level 2 | 5 | 5 | 0 |
| Level 1 | 2 | 2 | 0 |
| Durban classification | | | |
| Grade 1 | 11 | 3 | 8 |
| Grade 2 | 2 | 2 | 0 |
| Grade 3 | 8 | 8 | 0 |

Among the 13 surviving victims, six suffered surgical amputation, including two double amputations (arm and thigh; forearm and leg; Table 1). In one case, revascularization of the upper limb at the elbow was attempted but not successful, requiring secondary amputation. In two cases, reoperation was needed: one case for iterative debridement of a forearm wound associated with a skin autograft and the other previously mentioned case of secondary amputation. There were two cases of delayed wound healing that required treatment by second-intention healing. Negative-pressure wound therapy was used in these two cases. In two other cases, the victims underwent hyperbaric oxygen therapy.

A prehospital tourniquet was used in four of the five surviving victims who had an injury to a major vascular structure; one of these patients had two injuries: proximal humeral artery and femoral artery. In one victim who survived despite a major vascular injury due to proximal thigh amputation, no tourniquet was used but a pressure bandage was applied. None of the eight victims who died received a tourniquet; in one case, the proximal wound was not controlled by the surfboard leash used as a tourniquet. A tourniquet was used in two victims who suffered minor vascular injuries: one patient had a disarticulated wrist and ankle, and the other patient had a deep muscle wound in the thigh. In both cases, the tourniquet did not make the situation worse or create new injuries.

The average hospital stay in the surgery unit was 11.5 ± 9.8 days.

## DISCUSSION

This study's findings indicate that injuries following shark attacks are serious and that prehospital tourniquet use is a determining factor for a victim's survival. The death rate was 38% in this study, which is higher than the average 8.3% rate worldwide,[1,2] 11.6% in South Africa,[2] and 9.9% in Australia over the past decade.[11] Multiple injuries were present in 57% of our case series, but in only 1.2% of cases in South Africa.[2] Amputation was required in 46% of the surviving victims in our case series (15% on two limbs), whereas this rate was 6% in a South African study.[2]

One feature of shark bites is that the limb is stripped down to bone and the distal joint disarticulated (Fig. 1). Several other authors have described this injury pattern.[5–7,9] Stripping of soft tissues over a long bone and rupture of the stabilizers of the distal joint can be explained by the shark's interdental space and powerful jaw.[18] Most of attacks were due to tiger and bulldog sharks. Bulldog sharks are most often involved in fatal attacks. There were four cases of hand wounds. These may have occurred when the victim attempted to extract or defend himself from the shark, as described in some victims' accounts.[3,5,11]

Although the wounds are initially dilapidated and soiled by the environment (tropical water, sand), emergency surgical debridement helps to prevent deep infections. Certain authors have described frequent infection-related complications.[3] There is no published data that validates a specific course of prophylactic antibiotics.[9,19–21] Because there are no recommendations related to antibiotics, in our practice, we follow the recommendations for care of soft tissue wounds and open fractures.

The strong point of this study is that it is the only published study describing a case series of shark attack victims who were treated at a limited number of hospitals. The data were taken from medical records or from active or off-duty physicians who had initially treated the victims. An inventory of all the shark attacks throughout the world or in a particular region can be inaccurate, as it may be completed using information from media sources, nonmedical personnel, or people not involved in the victim's care.[2,7,8,12] Medical examiners have published case reports on pre- and postmortem attacks. However, these postmortem attacks do not fall in the context of clinical care needed to save a victim's life. Clinical and treatment-related data are not always included in their studies. Nevertheless, forensic studies are important because they include a realistic description of the injuries and the circumstances of the accident, along with clinical information. Multiple case reports have been published in this context.[3,15,20] It is hard to identify patterns with these varied cases, and statistical analysis should be interpreted with caution.

The victims have factors that increase blood flow and that hinder coagulation and arterial spasm—the typical victim is a young patient who is participating in an intense sports activity, who is in pain, and who has an acute stress reaction while struggling in tropical waters.[3] Only rapid application of a tourniquet was a determining factor for the survival of victims who suffered a proximal vascular injury, confirming other studies.[3,4,20,22] Among the victims who died, all had injuries to major vascular structures and none received a tourniquet, either because the body was not accessible or the injuries were too proximal on

**Figure 1.** Characteristic injuries following a shark attack. The bare bone is stripped of its soft tissues, and the distal joint is disarticulated.

the upper or lower limb. Hypovolemic shock was the most common cause of death in our case series, as in the literature.[3,4,6,15] The attack was fatal each time subfascial injuries of the trunk occurred (thoracic, abdominal, pelvic).[2,6] Any witness to a shark attack must not hesitate to apply a tourniquet, given the massive bleeding and the relative harmlessness of excessive tourniquet use, considering the availability of surgical treatment.[22–24] Immediate surgical care is the next requirement. Each time a victim was treated who was in cardiac arrest, he could not be revived despite use of cardiopulmonary resuscitation techniques.

To conclude, the number of human-shark contacts has increased in recent years due to an increase in the general population and in the participation rate in water-based sports.[3,11] Mortality has decreased because of the presence of lifeguards and rapid transport to a trauma center.[2,3,7] The availability of an emergency response kit with several tourniquets seems essential for sites that have a high risk of shark attacks.[2,4,23,24]

Our hearts and prayers go out to the victims of these attacks and their families.

## AUTHORSHIP

R.B. designed this study. R.B., G.S., and C.P. conducted the literature search. R.B. and C.P. collected data. R.B. performed data analysis. R.B. and G.S. contributed to data interpretation. R.B., G.S., and C.P. wrote the manuscript, which P.E. and E.P. critically revised.

## ACKNOWLEDGMENTS

We thank the orthopedic surgeons who participated in the collection of medical information: Dr. Pascal Boireau, Dr. Martin Fourquet, Dr. Jean-Marie Kalombo, Dr. Guillaume Nicolet, Dr. Frederic Sibilla, and Dr. Francis Vallier. We would like to express our gratitude to Seprodom for technical assistance.

## DISCLOSURES

The authors declare no conflicts of interest.

## REFERENCES

1. ISAF Home: Florida Museum of Natural History. https://www.flmnh.ufl.edu/fish/isaf/home. Accessed July 11, 2016.
2. Woolgar JD, Cliff G, Nair R, Hafez H, Robbs JV. Shark attack: review of 86 consecutive cases. *J Trauma*. 2001;50(5):887–891.
3. Caldicott DG, Mahajani R, Kuhn M. The anatomy of a shark attack: a case report and review of the literature. *Injury.* 2001;32(6):445–453.
4. Guidera KJ, Ogden JA, Highhouse K, Pugh L, Beatty E. Shark attack. *J Orthop Trauma*. 1991;5(2):204–208.
5. Ihama Y, Ninomiya K, Noguchi M, Fuke C, Miyazaki T. Characteristic features of injuries due to shark attacks: a review of 12 cases. *Leg Med (Tokyo)*. 2009;11(5):219–225.
6. Byard RW, Gilbert JD, Brown K. Pathologic features of fatal shark attacks. *Am J Forensic Med Pathol*. 2000;21(3):225–229.
7. Lentz AK, Burgess GH, Perrin K, Brown JA, Mozingo DW, Lottenberg L. Mortality and management of 96 shark attacks and development of a shark bite severity scoring system. *Am Surg*. 2010;76(1):101–106.
8. Ricci JA, Vargas CR, Singhal D, Lee BT. Shark attack-related injuries: Epidemiology and implications for plastic surgeons. *J Plast Reconstr Aesthet Surg*. 2016;69(1):108–114.
9. Davies DH, Campbell GD. The aetiology, clinical pathology and treatment of shark attack. *J R Nav Med Serv.* 1962;48:110–136.
10. Oceanographic Research Institute. http://www.seaworld.org.za/ori. Accessed July 13, 2016.
11. West JG. Changing patterns of shark attacks in Australian waters. *Mar Freshwater Res*. 2011;62(6):744–754.
12. Schultz LP, Gilbert PW, Springer S. Shark Attacks: Worldwide records through 1960 show when and where predaceous sharks are likely to attack man. *Science*. 1961;134(3472):87–88.
13. Trape S. Shark attacks in Dakar and the Cap Vert Peninsula, Senegal: low incidence despite high occurrence of potentially dangerous species. *PLoS One*. 2008;3(1):e1495.
14. Insee - Populations légales 2013 - 974-La Réunion. http://www.insee.fr/fr/ppp/bases-de-donnees/recensement/populations-legales/departement.asp?dep=974. Accessed February 16, 2016.
15. Clua E, Bescond PM, Reid D. Fatal attack by a juvenile tiger shark, Galeocerdo cuvier, on a kitesurfer in New Caledonia (South Pacific). *J Forensic Leg Med*. 2014;25:67–70.
16. Werbrouck A, Van Grevelynghe G, Landron F, Charlier P, Loire C, Gauthier C. Expertise médicolégale des victimes d'attaques et de morsures de requins à la Réunion. *La Revue de Médecine Légale*. 2014;5(3):110–121.
17. Gauthier C. Expertise médicale des victimes d'attaques de requins à l'Ile de la Réunion 2012.
18. Byard RW, James RA, Heath KJ. Recovery of human remains after shark attack. *Am J Forensic Med Pathol*. 2006;27(3):256–259.
19. White JA. Shark attack in Natal. *Injury.* 1975;6(3):187–197.
20. Rtshiladze MA, Andersen SP, Nguyen DQ, Grabs A, Ho K. The 2009 Sydney shark attacks: case series and literature review. *ANZ J Surg*. 2011;81(5):345–351.
21. Aziz H, Rhee P, Pandit V, Tang A, Gries L, Joseph B. The current concepts in management of animal (dog, cat, snake, scorpion) and human bite wounds. *J Trauma Acute Care Surg*. 2015;78(3):641–648.
22. Kragh JF. Use of tourniquets and their effects on limb function in the modern combat environment. *Foot Ankle Clin*. 2010;15(1):23–40.
23. Leonard J, Zietlow J, Morris D, Berns K, Eyer S, Martinson K, Jenkins D, Zietlow S. A multi-institutional study of hemostatic gauze and tourniquets in rural civilian trauma. *J Trauma Acute Care Surg*. 2016;81(3):441–444.
24. Schroll R, Smith A, McSwain NE Jr, Myers J, Rocchi K, Inaba K, Siboni S, Vercruysse GA, Ibrahim-Zada I, Sperry JL, et al. A multi-institutional analysis of prehospital tourniquet use. *J Trauma Acute Care Surg*. 2015;79(1):10–14; discussion 14.