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Title of Manuscript

Shark Related Injuries: A Case Series of Emergency Department Patients

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Shark Related Injuries: A Case Series of Emergency Department Patients

Introduction: Shark-related-injuries (SRIs) are not thoroughly evaluated in the medical literature given their rare occurrence. Previous studies involve the utilization of large-independent databases and have demonstrated that shark attacks appear to be increasing, even though mortality of SRIs has decreased from 51% in 1958 to 8.3% in 2001.

Methods: We performed a retrospective chart review on patients presenting to 10 emergency departments(ED) in southeastern Virginia from February 22, 2008 through December 31, 2016. We used a free-text search feature to identify patients documented to have the word "shark" in the record. We reported descriptive statistics for patient demographics, disposition, mortality, time of injury, body injury location, activity during injury, injury severity score (ISS), antibiotic use, and if the patient was in the International Shark Attack File(ISAF) or the Global Shark Attack File(GSAF).

Results. We identified 11 patients. Most patients were male (81.8%) and Caucasian (90.9%) with a mean age of 35 years old (SD=13.4, range17-55). Most patients (72.7%) arrived to the ED by private vehicle. Seventy-eight percent of patients were safely discharged from the ED. There were no deaths. There was a bimodal distribution of the time of injury around noon and early evening. Only 1 of our patients was present in the GSAF and 4 were present in the ISAF.

Conclusion: Most SRIs can be safely evaluated, treated, and discharged from the ED. Utilization of large databases for shark related research may underestimate its prevalence in the US. Further research is needed into the care of SRIs in the ED.

Introduction

Shark-related-injuries(SRIs) are a rare occurrence but they attract significant media coverage and public concern. These injuries are not thoroughly evaluated in the medical literature given the low number of events. Previous studies utilized three large independent shark attack databases,[1,2,3] the Global Shark Attack File (GSAF), the International Shark Attack File (ISAF), and South African Shark Attack File. Reports from these sources demonstrate that the number of events reported is increasing.[1] Fortunately, during this period the overall mortality from shark-related injuries has decreased from 51%[4] in 1958 to 8.3%[2]-11.6% in 2001.[3]

Injury Patterns

Reported injury patterns from shark attacks vary in the literature. These range from superficial lacerations and puncture wounds to deep lacerations, vascular injuries and amputations. One study reported 86 attacks in South Africa from 1980 to 1999, noting 83 lacerations, 5 traumatic amputations, 12 vascular injuries and 16 nerve injuries. Most lacerations were superficial and 80% occurred on the lower extremities.[2] A 2016 study of 5,304 shark attacks from 1990 to 2014 categorized injuries as unspecified (23.4%), minor (4.6%), and no injuries (14.2%), with most also occurring on the legs (41.8%).[1]

The Shark-Induced Trauma Scale (SITS) was introduced by shark researchers to consider blood pressure, location and depth of injury, extremity or organ loss of function, treatment, and patient survival.[2] Of the 96 attacks reviewed from the ISAF to develop the SITS, 40 (41.7%) consisted of Level 1 injuries, predominately simple lacerations, while 14 (14.6%) Level 4 injuries had deep tissue damage, loss of function or limb and level 5 injuries representing fatal injuries (8.3%).[2] Although these level 4 and 5 injuries exist, the literature suggests that the preponderance of injuries are more superficial and are possible to treat in an ED with patients discharged home.

Microbiology

The oral flora varies by species of shark and geographic location. In blacktip sharks in Florida, gram negative bacteria (61%) have been noted to be more frequent than gram positive (39%).[8] *Vibrio* species were found in 70% of great white shark samples.[9] While a consensus regarding antibiotic choice does not exist due to the variation in shark types, in black tip sharks from Florida it is recommended a fluoroquinolone or a combination of a third-generation cephalosporin and doxycycline for empiric antibiotic selection.[8]

Purpose

There has yet to be an ED-based study evaluating the care, complications, and characterization of shark injuries in the medical literature. Recent studies demonstrate that 42%-67% of SRIs require primary closure and no hospital admission,[2,3] highlighting the ED physician as paramount to the acute care of the shark-injured patient. Similarly, there is no consensus on the need for antibiotic prophylaxis in this population or an empiric antibiotic regiment.[3,5,6] The local EDs and two trauma centers included in the

current study cover over 10,000[7] miles of beaches in southeastern Virginia and northeastern North Carolina making the local acute care network unique to studying these events. We seek to describe a case series of emergency department visits for shark-injured patients.

Methods

We performed a retrospective chart review on patients with shark-related injuries presenting to 10 local EDs within an integrated healthcare organization in southeastern Virginia from February 22, 2008 to December 31, 2016. The hospital system uses EPIC as their electronic medical record (EMR) system. The institutional review board at Eastern Virginia Medical School approved this study with a waiver of consent due to its retrospective design.

We identified study patients using a free text search of the word "shark" within the ED documentation from the EMR. An initial 444 encounters were identified using this search term. We excluded 431 from our analysis because they did not have a true shark-related injury. The most common reason encounters were excluded were because the term "shark" was listed in the patients' medication list, the provider's name, or it was found in an allergy list. The remaining encounters were evaluated by two emergency physician reviewers (GW and RT) who extracted the discrete data from the EMR using an electronic form. The form consisted of 24 discrete questions (date, location, time of day) and four free text options for descriptions of: mechanism of injury, description of the injury, activity when the injury occurred, and procedures performed during the patient's hospital stays. We reviewed patient charts 30 days after the initial ED visit for complications. Complications were defined as a patient that returned to the ED requiring a change in the treatment plan.

Descriptive statistics summarizing patient characteristics were conducted using Microsoft Excel. These included patient demographics, injury characteristics, comorbidities, medications, consultant use, Injury Severity Score (ISS), Shark Induced Trauma Scale, procedures performed, ED and hospital LOS, patient charges, antibiotics use, culture data, and disposition. Data were analyzed at both the patient and encounter levels.

Results

Eleven patients presented to one of the 10 EDs with a shark-related injury during the study period. We found 11 patients with true shark-related injuries and one patient returned two additional times for a total of 13 encounters. Our study population had three patients that were admitted to the hospital and two of those went directly to the operating room (OR). In our cohort, there were no fatalities.

Characteristics of Patients

Most patients were male (81.8%), Caucasian (90.9%), with a mean age of 35 years old (*SD*= 13.4) and a median age of 36 years old. The youngest patient was 17 and the oldest was 55 years old. Most patients arrived by private vehicle (72.7%) while three patients arrived by helicopter (27.3%). The three patients that arrived by helicopter were admitted to an inpatient unit. In our cohort, no patients arrived by

ambulance. Table 1 provides the injury complex for the admitted patients. The age was purposely left out to protect the identity of the patient given the limited sample size.

Hospital Choice of Presentation

We investigated 10 hospitals, of these four hospitals had patients with SRIs. These f hospitals were within four miles of the Atlantic Ocean or the Chesapeake Bay. Two hospitals were trauma centers which evaluated 63% of the SRIs.

Time of Injuries

We had information of the time of the injury for eight patients. Shark-related injuries cluster in a bimodal distribution around noon(11am-2pm) and the early evening (5pm-8pm) during the day. SRIs were found to occur between June and September. Between 2009 and 2016, there were one to two SRIs per year in the study's geographic area.

Injury Complex and Activity during the Injury

Bite was the most common type of SRI (91%, *n*=10). One patient reported a contact injury to the knee causing a contusion. Most injuries occurred to the fingers. All patients discharged from the ED had superficial lacerations that required primary closure (Table 2). There were no tendon injuries noted in the patients that were discharged from the ED. Six patients were swimming in the water, while five were taking a shark off a fishing line. Of the patients swimming in the ocean, five were in waist deep water and one was scuba diving approximately 100 yards off shore.

Infectious Complications

Of the 11 patient encounters, six received empiric antibiotics (54%, *N*=6), three of which were ciprofloxacin, two doxycycline, and one clindamycin. Of the wounds that did not receive antibiotics; one presented four days after the bite occurred, one was from a small laceration to the hand, one was a contusion to the knee that did not violate the skin, and one patient went directly to the OR and had operative repair and washouts of their wounds. One patient in our study who did not receive empiric antibiotics had wound cultures done on hospital day 6 when the patient became febrile, resulting in gram negative rods (morganella morganii and enterococcus faecali). Doxycycline was used for the patient with the longest inpatient stay, while ciprofloxacin was most often prescribed for outpatient management.

ED Discharge complication

One patient returned to the ED after discharge from their laceration repair. The patient returned twice at planned intervals for wound care follow up and re-evaluation. There was no change in the original treatment plan. No other patient returned for follow up to our hospital system.

Comparison to the Global Shark Attack File and International Shark Attack File

Of the eleven patients with SRIs, one (9%) was listed in the GSAF and four (36%) were listed in the ISAF. All other encounters were not catalogued in these international databases.

Comparison of Injury Severity Score (ISS) and the Shark Induced Trauma Score (SITS)

Three of the eleven SRIs scored above a one on the ISS or on the SITS. With the ISS, two encounters scored a nine and another encounter was a four; all others had a low score of one. With the SITS, two encounters scored a four and one encounter scored a two while all other encounters were minor and scored a one with the SITS.

Discussion

This study is the first to utilize a hospital system's EMR to directly access patient records to characterize SRIs over an eight-year period. In our study, 73% of patients were treated in the ED and discharged without complication. Most had non-life-threating injuries and arrived by private vehicle.

Utilization of the large databases for the study of SRIs underestimates the prevalence of SRIs. Of our 11-patient cohort, only five were documented in the two shark injury databases. The small number of patients documented in these databases indicates that the true international number of shark attacks may be underreported, especially those bites with low ISS and SITS scores. The overall mortality rate for SRIs may be lower than previously reported as there were no deaths in our cohort. SRIs appeared to cluster in the summer months, with all 11 encounters taking place from June-September when water activities are at their highest. Regional shark migration patterns have been attributed to this as sharks tend to travel to warmer waters, as well as the increasing length of day in the summer.[12]

Previous studies found that most injuries occur below the waist[2]. Our cohort reported the lower extremity as the most common region of the body affected. It is reasonable to assume that victims are attempting to swim away from the shark and that this region of the body is submerged and accessible to sharks. The hand was the most common isolated body part in our sample (figure 3) that was injured. Half of these injuries were provoked and occurred while fishing and removing a shark from the fishing line while the other half occurred while the patient was trying to escape a shark attack.

Shark injuries appear to have low infectious complications. Most patients were treated as an outpatient with prophylactic antibiotics, primarily ciprofloxacin, and there did not appear to be any major infectious complications associated with the outpatient management of these bites. Current recommendations utilize a fluoroquinolone as a single agent or a combination of a third-generation cephalosporin with doxycycline.[8] Only three patients had appropriate antibiotic selection with a single agent of ciprofloxacin. No patients received dual antibiotic therapy. One patient received clindamycin which would not provide adequate coverage for vibrio. Further research in optimal antibiotic selection is required. The one patient's cultures that isolated morganella morganii and enterococcus faecali during hospitalization were most likely related to a nosocomial infection.

Limitations to this study include lack of access to any records of SRIs for patients under 18 years old. We did not have access to the EMR of the primary children's hospital in southeastern Virginia where pediatric patients may have been transported, however during the study period, the two trauma centers in our hospital sample were the only regional center for pediatric trauma. The retrospective nature of our study contains recall bias as we were dependent upon the memory of the patients.

Conclusion

Most SRIs cause soft tissue injuries and can be safely evaluated, treated, and discharged from the ED without outpatient complications. Utilization of large worldwide databases for shark related research may underestimate the prevalence in the US. Further research is needed into the care of SRIs in the ED.

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Figure 1. Number of Shark Related Injuries per hour of the day.

Figure 2. Number of Shark related injuries per month

Figure 3. Number of lacerations on each region of the body

Table 1 Admitted Patients

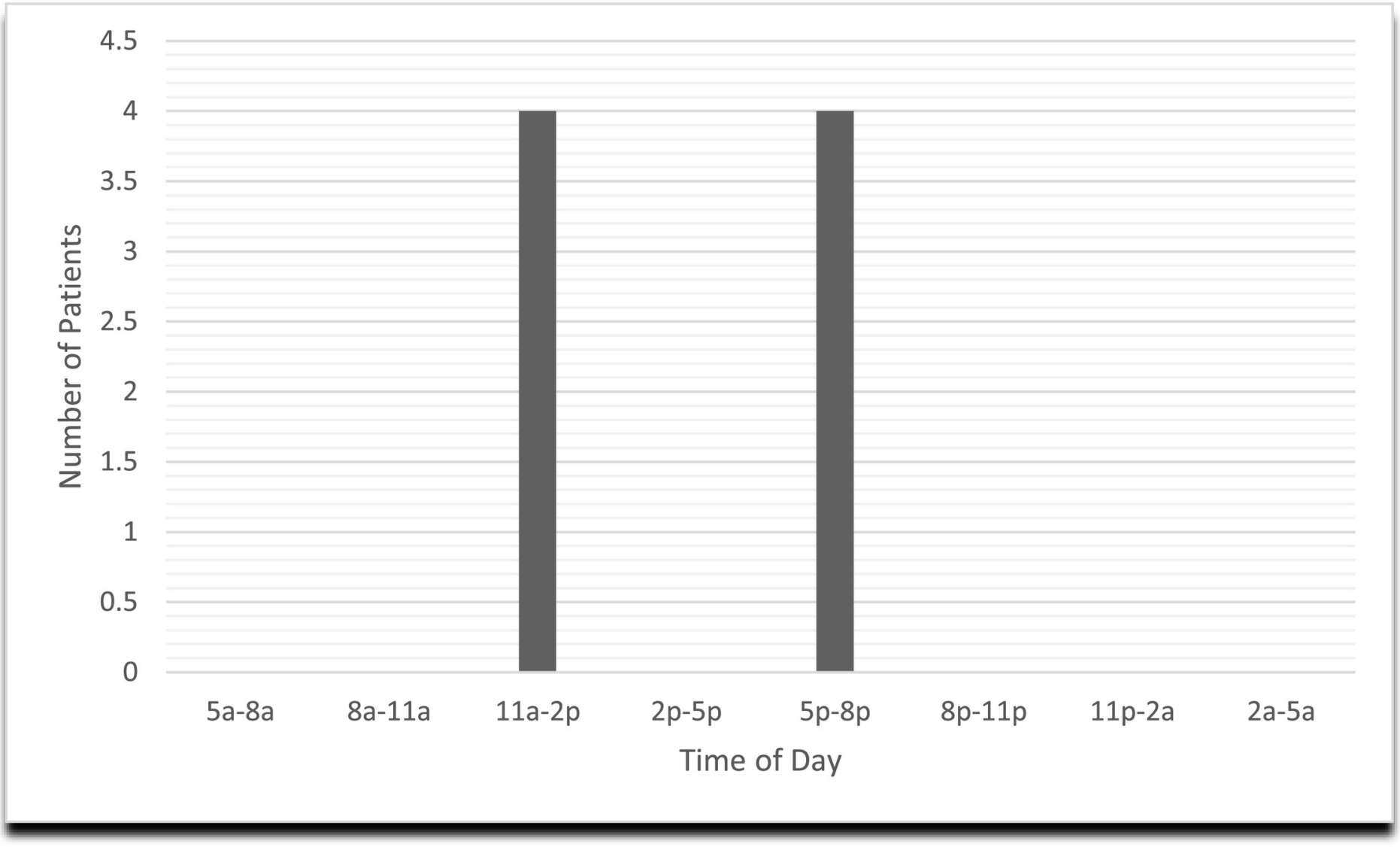
Patient Number	Sex	Injuries	Operations	Consultants	Antibiotics	Imaging
2	M	1.Right arm laceration 2.Decompression Sickness	None	Hyperbaric Medicine	none	Chest Xray: normal
9	M	1.Right sided back soft tissue injury 2.Right leg bite 3. Right lateral ankle with laceration	Excision and irrigation of Wounds (40cm)	Trauma, Anesthesia, Plastics Surgery	None	Tibia/Fibula Xray: Large soft tissue defect, no retained foreign body
10	M	1.Right lower extremity injury with large soft tissue defect 2. Right thumb bite 3. Right index finger bite right 4. Right deep intra-articular bite to knee	1. Washout RLE and BL hands with ligation of bleeding vessels 2. Repair of radial digital nerve to thumb 3. Repair of index finger metacarpophalangeal joint capsule 4. Wound Washout and Change of Wound Vac (X9) 5. Split Thickness Skin Graft to RLE	Trauma, Anesthesia, Plastic Surgery, Vascular Surgery	Doxycycline	None

Table 2 Discharged Patients

Patient Number	Sex	Injuries	Wound Repair	Consult	Antibiotics	Imaging	Return Visit
1	M	1 cm contusion/hematoma to right lateral knee	N/A	N/A	N/A	N/A	none
3	M	1.4 lacerations inferior to left knee. 2 on lateral aspect, 2 on medial aspect, each 3-5 cm, linear, no exposed tendon 2. 4 lacerations proximal to left ankle. 2 on anterior aspect, 2 on posterolateral aspect, 2-7 cm. Larger lacerations to lateral and anterior regions with tendon exposure but no laceration through tendon	Proximal tibia/knee region: Medial aspect: two 5 cm lacs repaired with 5-0 absorbable vicryl; then non-absorbable 4-0 nylon Lateral aspect: 3cm lac repaired w/ non-absorbable 4-0 nylon Distal tibia/ankle region: Anterior aspect: 2 Lacs (3cm, 7 cm) - repaired with 5-0 absorbable	none	Ciprofloxacin 750 mg q12 x 9 days	Left knee, left tibia/fibula, left ankle x-rays. No acute bony injury or foreign bodies	Returned 2 days later for scheduled wound recheck and 8 days later for another wound recheck with no complications

Patient Number	Sex	Injuries	Wound Repair	Consult	Antibiotics	Imaging	Return Visit
			vicryl and non-absorbable 4-0 nylon Lateral aspect: 3 Lacs (2cm, 2.5 cm) - repaired w/ non-absorbable 4-0 nylon and third lac also repaired with 4-0 absorbable vicryl				
4	M	Laceration to dorsal aspect of right hand distal to PIP joint of 2nd digit. Small vertical laceration through extensor tendon	5-0 ethilon to laceration, no tendon repair. Splinted	Plastics (Outpatient follow up in 2 days)	Ciprofloxacin 500 mg q12 x 7 days	X-ray of right fingers – no foreign body or fracture	none
5	M	Laceration to palmar aspect of left hand 3rd finger. Well approximated, no report of tendon injury	None. Patient left AMA	none	none	none (Declined by patient)	none
6	F	Right lateral thigh, 15 cm in cumulative lacerations, 8 separate lacerations and multiple small abrasion/puncture wounds	No ED laceration repair. Irrigated and dressed. Follow up with Plastics for delayed wound closure	Plastics (Outpatient follow)	Doxycycline 100 mg q12 x 7 days	none	none

Patient Number	Sex	Injuries	Wound Repair	Consult	Antibiotics	Imaging	Return Visit
7	M	1.2 puncture lacerations to left second distal finger pad. 2.Left third finger pad with multiple lacerations. 3 cm L shaped and 1.5 cm linear. No tendon injury	5-0 Ethilon of L shaped laceration and 5-0 Ethilon of linear laceration. Single layer closure	none	Ciprofloxacin 500 mg q12 x 10 days	N/A (Declined by patient)	none
8	M	3 lacerations to right lower lateral leg. 1 cm flap, 2.5 cm flap, 3 cm flap	2.5 cm flap repaired by 5-0 Ethilon. 3 cm flap repaired by5-0 Ethilon	none	Clindamycin 450 mg TID x 7 days	none	none
11	F	Multiple small superficial lacerations/abrasions to left lateral ankle	none	none	None	None	none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4
3.5
3
2.5
2
1.5
1
0.5
0
Number of Patients
5a-8a
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2p-5p
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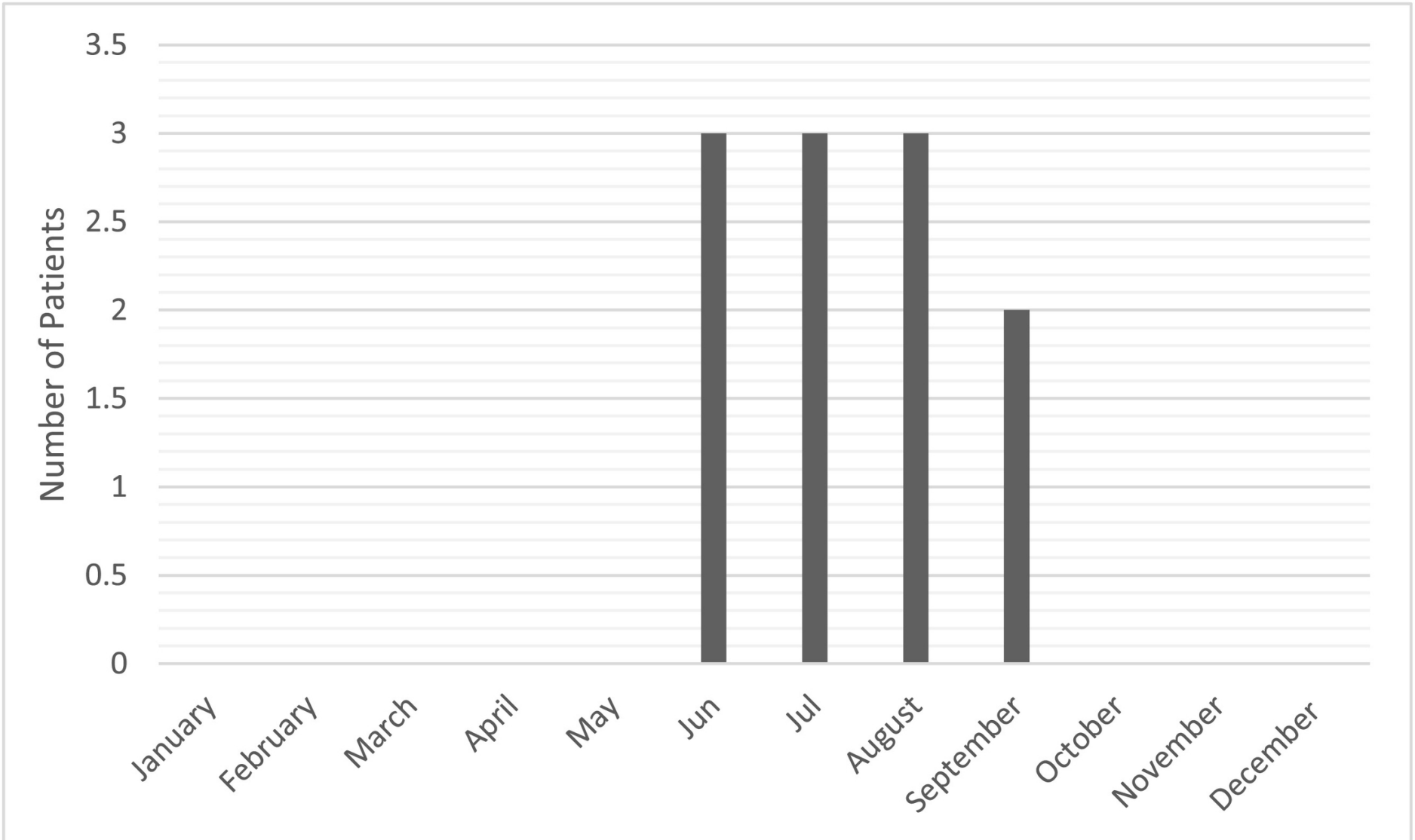
8p-11p
11p-2a
2a-5a
Time of Day

Figure 1


3.5
3
2.5
2
1.5
1
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Number of Patients
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February
March
April
May
Jun
Jul
August
September
October
November
December

Figure 2

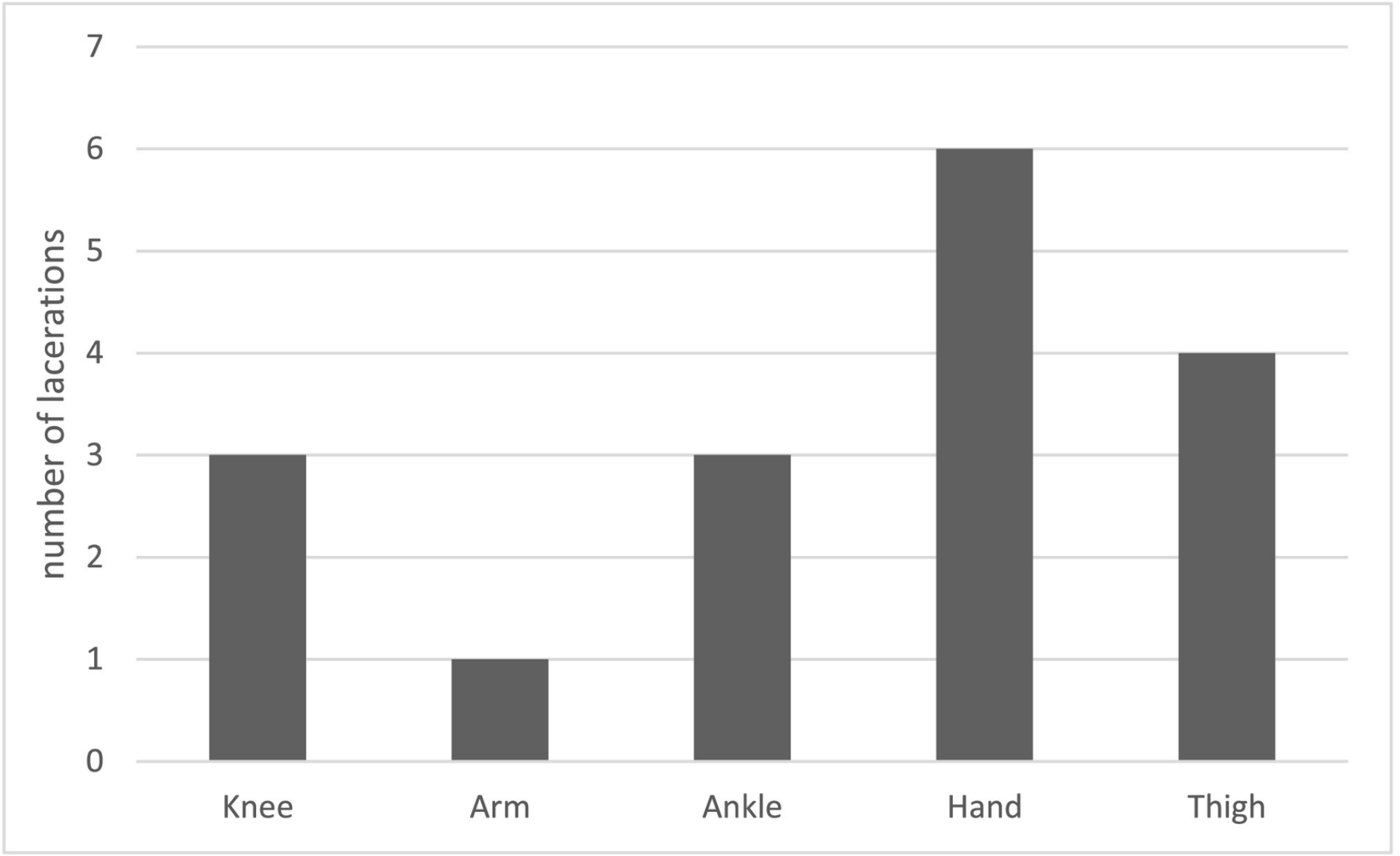

Figure 3