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CASE REPORT

PATHOLOGY/BIOLOGY

Dominique Semeraro,[1,†] M.S.; Nicholas V. Passalacqua,[2] M.S.; Steven Symes,[3] Ph.D.; and Thomas Gilson,[4,‡] M.D.

Patterns of Trauma Induced by Motorboat and Ferry Propellers as Illustrated by Three Known Cases from Rhode Island*

ABSTRACT: Understanding patterns of trauma is important to determining cause and manner of death. A thorough evaluation of taphonomy, trauma, and bone fracture mechanisms is necessary to reconstruct the circumstances of the death. This study examines the skeletal trauma caused by boat propeller strikes in terms of wound characteristics and location based on three cases from Rhode Island. These case studies review the traumatic characteristics caused by propeller injuries and highlight the anatomic regions most likely to sustain skeletal trauma. With this information, investigators may be able to identify propeller trauma even in severely decomposed remains. The discussion of boat propeller trauma also raises issues regarding how forensic anthropologists and forensic pathologists classify trauma (specifically blunt force vs. sharp) and highlights semantic issues arising in trauma classification. The study also discusses why these propeller cases should be classified as blunt trauma rather than sharp or chop/hack trauma. Ultimately, the authors urge consistency and communication between pathologist and forensic anthropologists performing trauma analyses.

KEYWORDS: forensic science, forensic anthropology, blunt force trauma, sharp force trauma, boat propeller injury, case study, boating accident

Patterns of trauma are widely accepted as a means for a forensic anthropologist to contribute to the determination of cause and manner of death in the medico-legal setting. In cases of skeletonized remains, the cause and manner of death are often determined based on the results of a forensic anthropological analysis. These results can reflect the anthropologist's prior experiences, anecdotal accounts of other casework, and experimental research. This occurs more often in cases with uncommon circumstances and a lack of previous experimental research to serve as a comparison. In addition to comparative research, an understanding of taphonomy and bone fracture mechanics is necessary to evaluate injuries with respect to timing (perimortem vs. postmortem) and potential lethality. In cases of decomposed bodies recovered from marine environments, the analysis of skeletal trauma is especially significant because of the multitude of confounding variables that can affect the appearance of the soft tissue. In these cases, it is the ability to recognize patterns of skeletal injuries and reconstruction of the taphonomic history of the individual that can be most helpful in understanding the circumstances of the death.

Throughout the United States, 137 trauma-related boating deaths were reported in 2007, with 80 injuries (fatal and nonfatal) because of propeller/motor strikes. In 2008, there was a minimal increase with 83 individuals injured in propeller-related accidents (1,2). While not a particularly common cause of injury encountered in a medico-legal setting, either a forensic pathologist or a forensic anthropologist may investigate such a case in the course of their career. This likelihood increases in areas where recreational boating, fishing, and water sports are more popular.

Literature on propeller trauma tends to have semantic issues. The fact that the propeller has what are referred to as "blades" and makes linear lacerations in soft tissue leads many to assume that the trauma is sharp (3,4). However, the blades on the propeller exhibit squared-off edges rather than "sharpened" beveled edges that are required to create sharp force incisions (5–7). Propeller injuries have previously been described as hack or chop injuries; however, this study proposes that this terminology is not accurate, as chop/hack trauma is defined as incised wounds to soft tissue with comminuted fractures of underlying bone (6,7). Further, we argue that chopping or hacking trauma terms are problematic as they inherently suggest the action, or the mechanism of injury, which may not always be accurate. Soft tissue damage from propeller strikes is the result of tissue tear or crush resulting in lacerations, rather than incising resulting in cut marks. Bone damage from propeller strikes results in *scoring* or fracture, not incisions. Finally, it is important to keep in mind the fact that incisions (as well as scoring, cuts, etc.) are a form of tool mark. While we classify *incisions* as sharp force trauma because of their creation

[1]Rhode Island Office of State Medical Examiners, 48 Orms Street, Providence, RI 02904.

[2]Department of Anthropology, Michigan State University, 354 Baker Hall, East Lansing, MI 48823.

[3]Department of Applied Forensic Sciences, Mercyhurst College, 501 E 38th Street, Erie, PA 16546.

[4]State of Connecticut Office of the Chief Medical Examiner, 11 Shuttle Road., Farmington, CT 06032.

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[†]Present address: Albany Medical College, 47 New Scotland Avenue, Albany, NY 12208.

[‡]Present address: Cuyahoga County Medical Examiner's Office, 11001 Cedar Ave., Cleveland, OH 44106.

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with a beveled object, nonbeveled objects can create similar *lacerations* that are not the result of sharp force injury.

This study presents three cases of fatal injuries sustained from motorboat and ferry propellers, to define exemplar patterns of trauma when dealing with cases of remains recovered from marine contexts with unknown circumstances surrounding the death event. Further, characteristics from these injuries will be used to discuss differences in sharp versus blunt force trauma classifications from forensic pathologists and forensic anthropologists.

Case Reports

In 2007, the Rhode Island Office of State Medical Examiners investigated three unrelated cases involving decedents who had been struck by motorized boat propellers.

Case 1

The propeller of an open motorboat struck a young male individual in the water as the boat approached him at a relatively low speed. The decedent had two parallel lacerations to the head with underlying trauma to the cranium, comminuted fractures of the left proximal radius and ulna, multiple parallel lacerations to the posterior aspect of the left leg, and comminuted fractures of the left distal tibia and fibula. The trauma to the cranium resulted in two major parallel fractures, one running from the mid-frontal region through part of the left parietal to the left temporal bones and a second running from the right temporal through the right parietal to the occipital (Fig. 1).

While these fractures may appear to mimic sharp force trauma, close inspection reveals delamination (separation of the outer and inner tables of the cranial bones, a characteristic of blunt force trauma) of portions of the cranial vault and additional fractures that radiate from the primary impact points. The intercranial surface of these fractures shows inward beveling and more radiating fractures (Fig. 2).

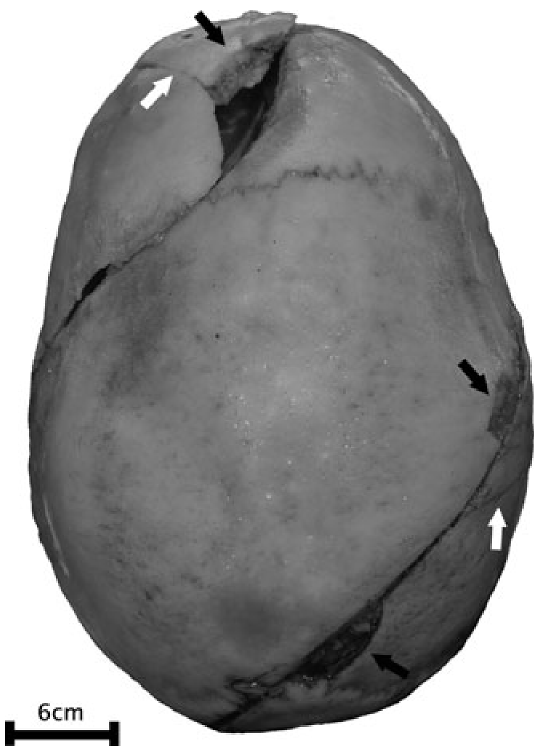

FIG. 1—*Superior view of decedent's calvarium. White arrows point to radiating fractures. Black arrows point to delamination.*

Case 2

A young male individual was reportedly struck by an open motorboat propeller operating at a relatively fast speed after he fell overboard. The decedent had multiple parallel lacerations to the posterior head, neck, and torso (Fig. 3), cubital region of the right arm, and posterior portions of the right leg. Examination of the decedent's internal organs revealed lacerations of the right lung (Fig. 4) and lateral surface of the liver (Fig. 5). Trauma to the skeletal elements of this individual included a one-inch scoring defect to the right side of the occipital bone. Also, right ribs 6–12 were fractured in the posterolateral region. The ribs were splintered with multiple longitudinal fractures and bony intrusions into the pleural cavity.

Case 3

An elderly male individual was believed to have suffered a cardiac event and fell into the water by a ferry launch. The decedent's body was discovered damaged and severed when the ferry launched almost 12 h later. The body sustained fractures to every rib and the

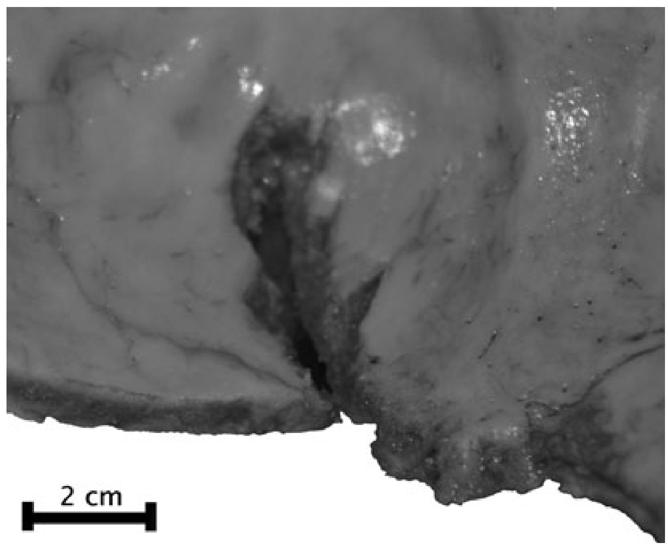

FIG. 2—*Intercranial surface showing an irregular inward bevel and additional radiating fractures.*

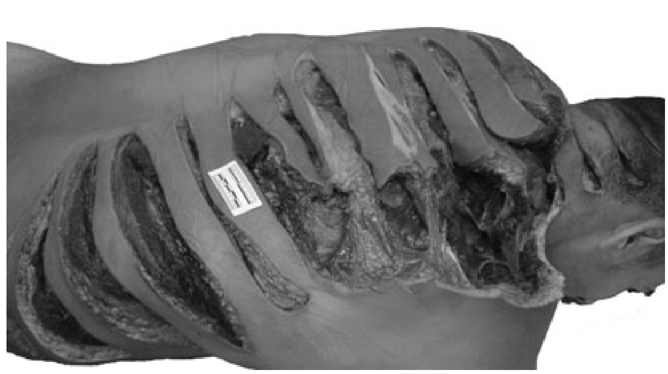

FIG. 3—*Propeller trauma to decedent's back.*

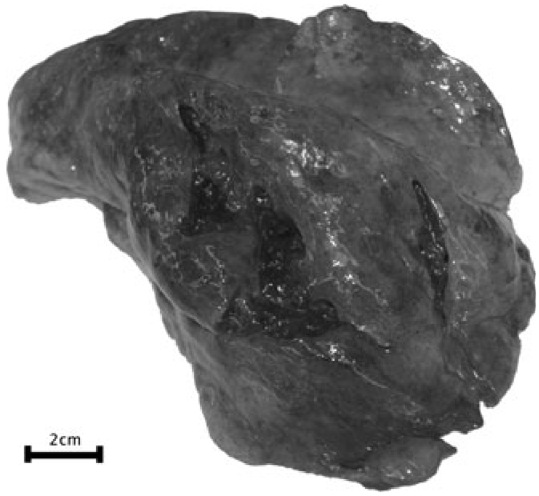

FIG. 4—*Right lung showing lacerations.*

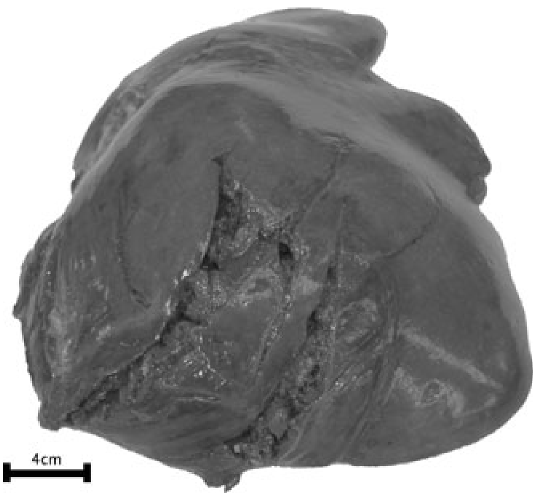

FIG. 5—*Lacerations to the greater lobe of the liver.*

vertebral column was fractured at T4 and severed at the T8 level. The decedent's head shows an impact that removed the frontal bone and portions of the parietals and zygomatic bones. This impact created an interesting cross-section of the calvarium, which shows delamination and radiating fractures (Fig. 6). Both arms sustained comminuted fractures, and the left radius shows a classic blunt force trauma signature of a "butterfly" fracture (Fig. 7).

Overall, the impact from the ferry propeller caused significant damage to the decedent, unlike the motorboat propeller impacts. In this case, the body was completely severed in the abdominal region and only the upper portion was recovered. Unlike the previous cases, this individual lacked the unilateral patterned propeller impacts. Further, the bony fractures (being caused by a similarly shaped, but *c.* 10 times larger propeller) were obvious blunt force injuries. Vital organs were no longer present to evaluate at autopsy.

Discussion

Cases 1 and 2 exhibit similar patterns with longitudinal parallel propeller blade impacts that traverse portions of the body (Fig. 8). In each case, the propeller impacted the cranium and the extremities. The propeller trauma in both decedents was limited to one side of the body. Cases where extremities on both sides of a decedent

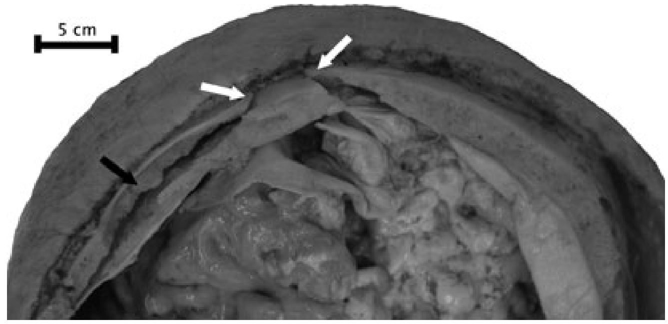

FIG. 6—*Anterior view of the decedent's cranium. White arrows point to radiating fractures. Black arrow points to delamination.*

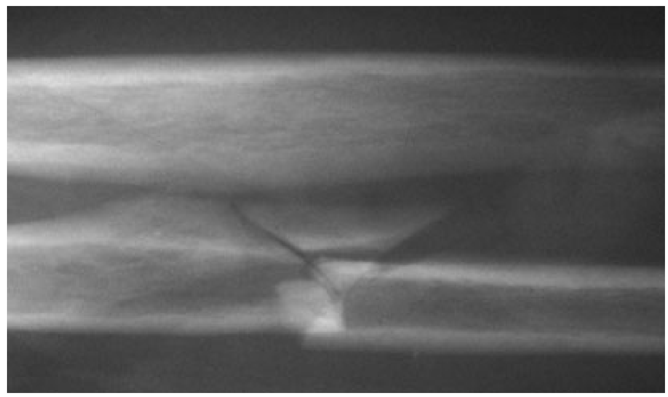

FIG. 7—*Radiograph showing a butterfly fracture of the left radius.*

are affected may indicate multiple passes of the boat or a boat with dual propellers. Parallel abrasions either precede or follow deeper lacerations that penetrate the skin and subcutaneous layers. In Cases 1 and 2, the propeller strikes to the cutaneous tissue are classified as abraded contusions until the cutaneous tissue is penetrated at which point pathologists classified them as "incised-type wounds" or "chop wounds." However, chop wounds are defined as incised wounds to skin overlying comminuted fractures or grooving in bone (6,7). Propeller soft tissue trauma seen in the exemplar cases exhibited abraded and contused margins that are not characteristic of sharp force trauma.

While impacts to the extremities and torso created skeletal trauma easily recognizable as blunt force, impacts to the cranium created somewhat linear fractures with primarily smooth fracture edges that could be mistaken for sharp force injuries. However, they are considered the result of blunt impacts because the shape of the edge on a standard propeller blade is "squared-off," rather than beveled (5). Owing to the squared edges of the propeller blade, "scoring" can and does occur on the bone; however, this is not a true sharp force trauma because of the lack of edge bevel of the cutting instrument. The decedent in Case 2 also sustained blunt force lacerations to the lungs and liver that appear as linear defects yet are the result of tears in the soft tissue rather than incised cuts.

These cases exhibit blunt skeletal injuries caused by standard propellers at different speeds. These produced patterns of trauma similar to other case reports (8–14) and experimental research (12). Ihama et al. (8) found multiple parallel lacerations to skin and subcutaneous tissues and "crush injuries" to internal organs in their study of several individuals struck by propellers. Stubblefield (9), when detailing a propeller strike case analyzed by Dr. William Maples, found linear fracture patterns to the skeleton, transected

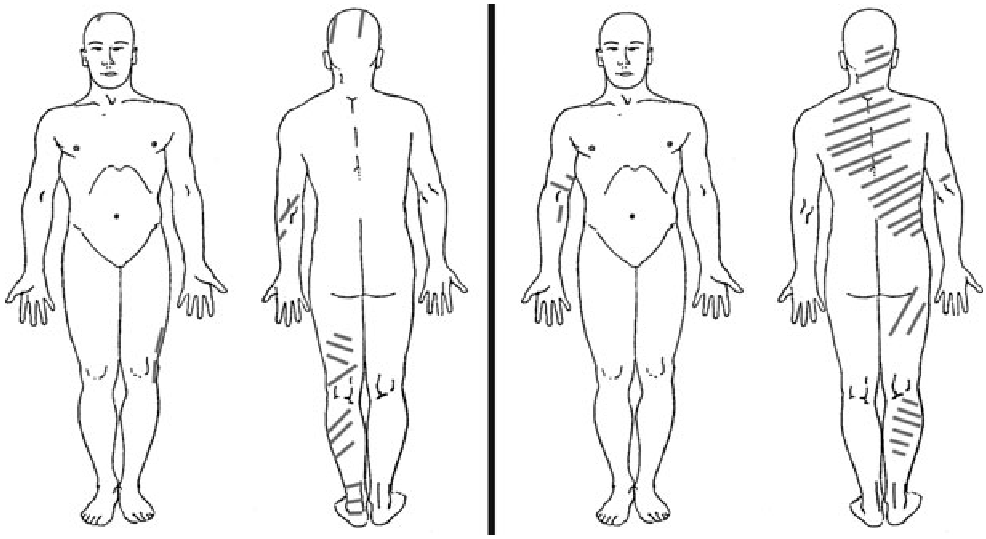

FIG. 8—*Anterior and posterior views of the body showing areas of trauma in Cases 1 and 2. Gray lines indicate propeller strikes.*

bone, and comminuted fractures. In a case of an individual struck by a propeller of a dinghy, DiNunno and DiNunno (10) found the body sustained multiple parallel "lesions" and "lacerations." The article, however, describes the lesions as having clearly outlined borders rather than ragged ones. Kutarski (11) describes propeller wounds as having a crushing element, especially in deeper wounds. Ralston (12) recounts a case where an individual survived a propeller strike to the head but sustained a coronal scalp laceration in the right mid-parietal region and a comminuted fracture where a large fragment of bone had been broken off and rotated away from the skull. Yu et al. (13) analyzed 100 autopsy cases of propeller injuries and found evidence that propeller injuries can be distinguished from cutting and dismemberment from sharpened instruments.

Previously, Kroman et al. (15) discussed experimental patterns of injury and injury mechanics from propellers in relation to speed at impact and propeller style. Their research discussed trauma in terms of blunt and sharp force trauma to human cadavers and euthanized pigs (*Sus scrofa*) in an experimental setting. The results were that a standard propeller, such as in Cases 1 and 2, caused "incisive, sharp force injuries" that affected soft tissue and bone when it impacted a cadaver at a low speed.

Interestingly, the trauma induced on these remains (in both the reported cases and experimentally) was examined with differing interpretations based on forensic pathology versus anthropology backgrounds. Previous authors and the present examining forensic pathologists considered the trauma to be a result of sharp force because of the clean separation of the soft tissues. However, the hard bony tissues demonstrate typical blunt force injuries, lacking sharp force cuts or incised wounds. The present authors suggest that perhaps because of training differences and trauma classification considerations, these differing interpretations are not mutually exclusive. Sharp force trauma is caused by an incising (cutting) of material by a beveled edge (16–18 and references therein), whereas blunt force trauma is characteristic of slow loading of bone, usually resulting in linear or concentric fractures (19). It should be noted that sharp force trauma also occurs at these slow loading speeds (5). What is crucial is that wound shape in either case is defined by the shape of the object or, more accurately, the contact surface and force of the impacting object (in these cases, boat propellers). Thus, it may be more helpful to think of trauma as a continuum as recently recommended by Kroman (20).

What we are interpreting as "cut marks" or "stab wounds" are simply tool marks left by sharp (beveled) instruments. Tool marks can take any shape depending on the shape, contact surface, and force behind the impacting object (21). In sharp force cases, the knives, saws, hatchets, axes, etc., all have sharp (beveled) edges that produce the incised marks. In the case of boat propellers, the edges of the "blades" are not beveled but squared-off, despite the narrow focus of impact. Often in cases with an object lacking a sharp (beveled) edge, when it impacts bone, the result is scoring, shaving, or scraping (as opposed to incising) of the surface (5). However, if an object with a squared-off edge impacts soft tissues fast enough, it may produce a clean lesion resembling a cut (incised wound) instead of tear (laceration). This is what appears to be occurring in these propeller cases. Thus, while there may be terminology discrepancies about trauma to soft tissues, the trauma to skeletal material is characteristically blunt, lacking sharp force incisions. Although the impacting tool is the same, interpretations appear to differ for soft and hard tissues between forensic pathologists and anthropologists because of the object shape and rate of loading (impact) to the soft versus hard tissues.

Case 3 differs from Cases 1 and 2 in the sheer magnitude of force of the ferry propeller and the resulting trauma to the body. The decedent's head bears a linear fracture that has separated a portion of the cranium; this fracture pattern is similar to the fractures to the decedent's head in Case 1, where the fracture seems to be guided by the "blade" as the split in a log would be guided by a chisel/wedge. Helpern (14) recounts a case where a decedent was dismembered postmortem by a ferry propeller. The great amount of energy involved in the trauma to the decedent in this case is similar to other documented high-energy impacts such as plane crashes and train strikes. Bodily fragmentation, thoracic transection, amputations, and extensive soft tissue mutilation have also been recorded in cases where a decedent was struck by a locomotive (22).

Symes et al. (23) indicate that from an anthropological standpoint, the perimortem interval exists as long as bones retain their fresh properties (are in a wet state). The postmortem interval then sets in once skeletal tissues lose their elastic properties (i.e., are in a dry state). This point is exemplified by Case 3. If the remains had decomposed to the point of skeletonization prior to being stuck by the propeller, the macroscopic trauma could still appear to the forensic anthropologist as having occurred during the perimortem interval. However, the lack of soft tissue hemorrhage at impact sites leads the forensic pathologist to identify the propeller trauma as postmortem. Concerning this case, the circumstances, and video footage of the ferry launch site, are the most indicative of the timing of the trauma.

Conclusions

These case studies provide a review of blunt force injury characteristics caused by boat propellers as well as highlight the anatomic regions most likely to sustain skeletal trauma. Key features in propeller strike cases include multiple linear-parallel abrasions and/or deeper parallel lacerations that penetrate the skin and subcutaneous layers, linear fracture patterns to the skeleton, transected bone, and comminuted fractures. Injuries from larger propellers have characteristics that are similar to other high-energy impacts. Additionally, if the propeller strikes affect the torso or head, there may be damage to underlying vital organs. In the first two cases, "typical" propellers—albeit at different speeds—were shown to cause similar patterns of blunt injuries to the skeleton. This corresponds to other reported cases and to experimental research (8–15). The third case represented injuries associated with a large ferry propeller. Because of both the greater amount of energy needed to operate this propeller and the larger blade size, the majority of the skeleton exhibited injuries associated with blunt trauma.

These descriptions, coupled with an understanding of blunt force trauma biomechanics, should allow an examiner to compare patterns of documented boat propeller injuries, even in severely decomposed bodies. These comparisons can aid in determining the cause and manner of death in marine fatalities.

Discrepancies in the interpretation of "sharp" versus "blunt" forces are because of diagnostic differences found in the tissues and in the definition of these traumata. Yet, the question remains: why did the soft and osseous tissue from a single impacting surface, in this case the boat propeller, exhibit different classes of trauma? If a further microscopic examination of the soft tissue was conducted, the "incised" edges of the wound may have demonstrated an abrasion edge as a result of the narrow, flat-edged impacting surface and may also indicate a microscopic irregular skin separation. The feature can be used to indicate a blunt rather than sharp injury, but these features are likely difficult to see because of the narrow focus of the blade.

Shaved edges of the thin blade traumatized bone are likely visible to the naked eye during examination. Unless these features are evaluated under magnification, these edges may be all but impossible to distinguish from sharp force injury, where the 90° angle of the blade, may create a straight line impact surface or shaving mark to the bone.

While neither description of sharp versus blunt is necessarily incorrect, it is important for forensic investigators collaborating on casework to keep in mind the semantic differences when discussing this type of circumstances and never to neglect the opportunity to more closely examine a traumatic injury. Overall consistency in the usage of terminology and accurate description of traumatic wounds is key to communicate the conclusions from trauma analysis. Finally, perhaps (as argued by Kroman [20]), the current classification system for trauma is too restricting and trauma analysis should move toward this continuum-of-trauma approach instead.

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Additional information and reprint requests:
Dominique Semeraro, M.S.
Albany Medical College
47 New Scotland Avenue
Albany, NY 12208
E-mail: semeraro@gmail.com