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Case Report

Combining anthropology and imaging to reconstruct antemortem trauma for identification purposes

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Abstract

Identification of unidentified remains involves a comparison of ante- and postmortem features using biological identifiers. Anthropological identifiers, referred to by International Criminal Police Organization (INTERPOL) as secondary identifiers, have often been judged less reliable than DNA, fingerprints and dental records (referred to as primary identifiers). However, anthropological identifiers have been proven as discriminatory as the primary sources in many instances, and play a decisive role in positive identification. To guarantee better use of anthropological identifiers, it is not only essential to develop standard protocols and statistical frameworks, but also to test different identification approaches in cases from daily practice. Evidence of skeletal antemortem trauma can be a valuable aid in the identification process, especially if the exact type of traumatic event causing the injury is identified. Here, we present a case in which the combination of anthropological analysis and imaging confirmed an interesting and unique sequence of antemortem traumatic events in incomplete skeletal remains. The remains were assumed to pertain to an individual who went missing several years earlier, and whose medical records revealed a unique history of trauma to the right femur. The individual had sustained a fracture due to a fall from a high height followed, 10 years after the primary trauma, by a gunshot wound to the same bone; both treated by intramedullary nail fixation. While the anthropological analysis matched the biological profile of the missing individual and identified a healed defect to the right femur compatible with a gunshot wound, the radiological examination indicated that the bone underwent three surgical procedures on different occasions. Radiological examination also identified a pre-existing healed fracture adjacent to the gunshot defect. In addition to presenting the identification process in this specific case, this article discusses the difficulties in antemortem trauma interpretation, importance of combining macroscopic and radiological analysis to aid the reconstruction of previous traumatic events and mechanisms of injury from healed fractures that can play important roles in forensic human identification.

Key points

- Anthropological identifiers can have a decisive role in forensic identification.
- A multidisciplinary approach to the analysis of skeletal antemortem trauma can increase the amount and quality of the collected data.
- Guidelines on how to analyse and report features when evaluating antemortem fractures on bone can aid in extraction of complete and informative data for identification purposes.
- Studies aimed to understand traumatic and posttraumatic events from discrete traits of healed fracture could facilitate identification using antemortem trauma in the future.

Keywords: antemortem trauma; forensic anthropology; identification; secondary identifiers

Introduction

Gathering information that can aid in the identification of unknown deceased individuals is an essential part of medicolegal and death investigations, and one of the main tasks for forensic practitioners. Although fingerprints, dental profiles and DNA, often referred to as primary identifiers, are considered the most reliable means of identification [1], their applicability can be limited, even in cases with presumed identities. This can be owing to the impossibility of retrieving postmortem data (e.g. in remains in advanced decomposition, or in those severely damaged or fragmented by biological and physical factors) or the unattainability of antemortem information (e.g. no living relatives, or the inexistence or destruction of antemortem records) [2–4]. Previous experience from the field has shown that, especially in events involving large-scale disasters, identification has, at least initially, largely relied on methods considered less reliable, such as visual identification and personal effects recognition [5–7]. The ongoing humanitarian migrant crisis is another example where legal and socioeconomic challenges limit not just the use of primary identifiers as a means of identification, but the identification process itself [7–11]. In these cases, antemortem data are often restricted to information obtained from next of kin and other relatives. Additionally, postmortem data collection is severely limited owing to the lack of adequate funding and operational infrastructure. In such instances, the so-called

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secondary identifiers (personal descriptors, medical findings and corporeal changes) may well be the only means to render an identification. International Criminal Police Organization (INTERPOL) has acknowledged the importance of secondary identifiers in complex identification cases, stating that these types of data have potentially equal importance for identification as that of primary identifiers and that "in combination may provide sufficient information to make identification in selected cases" [1].

In 2020, the Forensic Anthropology Society of Europe (FASE) stressed the importance of anthropological features — such as corporeal, facial and skeletal traits — and efforts to develop new methods to facilitate their comparison and use in practice. The FASE Board argued that "properly applied forensic anthropology methods can be used for identification, especially in situations with limited applicability of traditional methods" [2]. Biological identifiers, including anthropological traits, are certainly more person-specific and discriminatory than other features included among secondary identifiers, such as interchangeable personal effects. Anthropological identifiers, even if somehow neglected after the rise of DNA profiling methods, have been proven crucial for identification, either alone or in combination with other methods [12–30]. To enhance the use of anthropological traits for identification purposes, it is important to establish clear guidelines on data collection and analysis, create robust and appropriate statistical frameworks and define the minimum number of matching features required for positive identification, while considering the circumstances of the findings [3, 31]. Furthermore, by enhancing interdisciplinary collaboration and by implementing new technologies in osteological assessments, the methods currently used for bone analysis and the extraction of identificatory information from skeletal material could be further refined and the existing limitations overcome. Understanding how different bone features can be used for identification purposes requires not just prospective studies, but also case reports in which the identificatory potentials of various bone features can be evaluated in real-life cases.

Here, the authors present a case in which a complex series of antemortem traumatic events was identified through targeted radiological and anthropological analyses, guided by retrieved antemortem data. The paper also explores the identification potentials and limitations of antemortem trauma analysis while considering current recommendations and future perspectives.

Background

Incomplete, but intact, skeletal remains comprising cranial and a number of postcranial elements, including a right femur were found in a wooded area in Southern Sweden. The on-site search was performed by police (in accordance with Swedish practices at the time of the finding) who could not locate any other skeletal elements despite searches done in the area. The police suspected that the remains pertained to an individual who had been reported missing in the same area 15 years before the finding. The biological profile (sex, population affinity, age and estimated height) reconstructed by the anthropological analysis of the remains matched the profile of the missing person. During the identification attempts, antemortem data, including some of the person's medical records, were gathered by the police and provided to the forensic pathologist to ease the identification. The documentation revealed that the individual suffered two specific traumatic events to the right leg on two different occasions. Even though the remains were ultimately identified using dental comparison (approximately 80% of cases in Sweden are identified by odontological comparison), anthropological and radiological data were used to assess whether the unique traumatic sequence reported in the medical records could be identified and reconstructed from the remains. The analysis was driven in part by known antemortem information. The analysis aimed to identify specific features in the femur that could indicate the two separate traumatic events that caused them, and to determine whether the features were sufficiently clear and distinctive to allow for correct interpretation of the lesions even in the absence of medical records. To diminish the risks of contextual bias [32, 33], sequential unmasking of medical information was used during the examination. The retrieved information was objectified when possible, and the evaluations were structured and collaborative, where alternatives to the observed features were broadly considered and discussed while considering the differential diagnosis.

Missing person data—medical records

The medical records submitted to the legal medicine department by the police comprised only written reports (radiological documentation could have been retrieved later, but because the remains were subsequently successfully identified, this was not done). The reports revealed that, 2 years prior to disappearing, the missing person suffered a perforating gunshot wound (GSW) to the right leg. The entrance wound to the soft tissue was described as located in the ventral thigh, approximately 5 cm above the superior margin of the patella, with the exit wound located approximately 10 cm above the popliteal region. The bullet passage destroyed the ventral, lateral and posterior portions of the distal femoral shaft, leaving only the medial aspect intact (approximately 1/3 of the shaft surface area in this region). The preserved section, according to the descriptions provided, showed no defect or fracture. However, no information on the size of the bone lesion was provided. Foreign material, most likely shattered bone and bullet fragments, were found and had been mostly removed from the wound channel and surrounding soft tissue.

The individual's medical records indicated that the femoral fracture was initially stabilised using an external fixation device. Eight days later, the surgical team proceeded with intramedullary nail surgery. The external fixation device was removed, and an intramedullary nail measuring 400 mm in length and 11 mm in diameter was placed in the femoral medullary cavity.

The area of the skin incision and wound became infected nearly one and a half months after the surgery, but follow-up indicated no further complications or bone involvement. Owing to the absence of medical records beyond 4 months after the injury, later posttraumatic complications could not be completely ruled out.

Another interesting fact that emerged from the medical records was that the individual had suffered an open fracture to the same bone 10 years prior to the GSW. No additional information about the type or extent of the fracture was provided. However, the records indicated that the fracture was caused by a fall from a height of approximately 10 m, and that the fracture was treated with intramedullary nailing. The implant was removed 7 years after the injury (3 years prior to the GSW) because of subjective discomfort caused by the implant caused the individual.

No information on the serial numbers of the nails could be retrieved from the medical records.

Postmortem data

Anthropological analysis

The macroscopic analysis of the right femur revealed a complete bone with moderate taphonomical changes on the articular surfaces. Cortical bone was absent in patchy areas on the articular surfaces, with discrete scavenging marks. Grown-grey discolouration was evident on the femoral shaft, which was characterised by an intramedullary nail running from the greater trochanter to the distal femur, where two screws protruded through the medial aspect of the metaphysis (Figure 1A).

In the distal femoral shaft, 9.5 cm above the caudal border of the lateral condyle, an irregular circular defect with rounded margins measuring 3.7 × 1.8 cm was noted and which exposed the intramedullary nail in the posterolateral femoral shaft. The remainder of the shaft was intact (Figure 1B). The defect was surrounded by sclerotic callus formation. On the anterior surface of the bone and superior to the defect, a 5-cm area was noted that appeared as mediolateral bulging with a chronic periosteal lesion (Figure 1C). The appearance of the injury was deemed compatible with a healed comminuted fracture where part of the bone has been lost or shattered, a scenario commonly observed in GSW. Additionally, the location of the defect matched that described in the medical records, and the injury was focal and appeared not to have affected the entire shaft circumference, suggesting a localised traumatic incident. However, because comminuted fractures are not exclusive to GSW (high-energy blunt force trauma and explosive trauma can also cause extensive comminuting), the appearance of the injury could not be considered conclusive evidence of a GSW. On the basis of the appearance of the defect, an infectious origin for the lesion could likewise not be excluded.

Neither definitive signs of several traumatic events nor defects compatible with the existence of previous medical intervention to the bone could be detected macroscopically, even though the observed lateromedial bulging (Figure 1C) could have indicated a separate condition (e.g. trauma or pathological condition). However, it was impossible to completely exclude that the two defects originated from the same condition.

It was impossible with only morphological macroscopic analysis of the femur to obtain more conclusive and discriminatory information on the diverse medical treatments to the bone. Therefore, because it was not possible to confirm with high certainty the traumatic event that led to the observed defect or those that may have preceded it, it was decided to proceed with computed tomography (CT) and radiological examination to answer the following questions: (i) Is it possible to confirm that the defect in the bone with the subsequent callus development was the result of a GSW? (ii) Is it possible to confirm or exclude an inflammatory process in the bone subsequent to the fracture? (iii) Is it possible to identify a sign (lesion or other changes) to the bone caused by the 8 days of external fixation of the femoral shaft? (iv) Is it possible to confirm that the bone underwent intermedullary nail surgeries on two different occasions? and (v) Is it possible to identify traces of a previous femoral fracture?

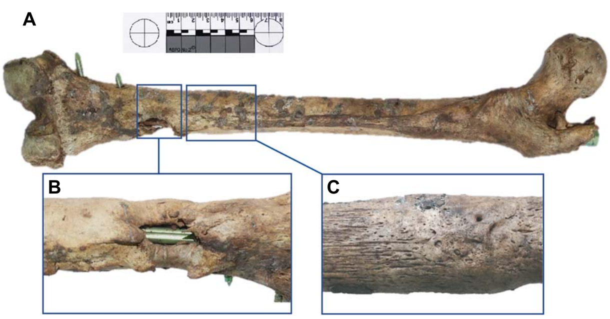

Figure 1 Right femur with a visible intramedullary nail (A), distal posterolateral defect (B) and lateromedial bulging with periosteal reaction on the anterior aspect of the shaft located 5 cm above the defect (C).

Radiological analyses

The femur was scanned with a Dual Source Siemens SOMATOM Force CT scanner (Siemens Healthineers, Forchheim, Germany) using the following parameters: field of view: 129 mm, tube current: 426 mA and potential: 150 kV, slice thickness: 0.75 mm and two reconstruction kernels: Br64s for multiplanar and Bf32s for three-dimensional reconstruction.

The CT images showed an intramedullary nail measuring 400 mm in length, which was the same length as that reported in the individual's medical records, with metal fragments along its course and in the vicinity of the screws.

The bone also showed transverse, band-shaped and narrow defects in the shaft, which corresponded to previously removed screws. These were observed in the proximal femur, just below the greater trochanter, in the central and distal femoral shaft. On the basis of the different locations, number, distribution and path of the screw-like defects, as well as their relation to the intramedullary nail and their depth, it was concluded that these defects originated from an earlier external fixation of the bone (Figure 2A and C, open arrows), as well as an earlier intramedullary nail surgery (Figure 2B,

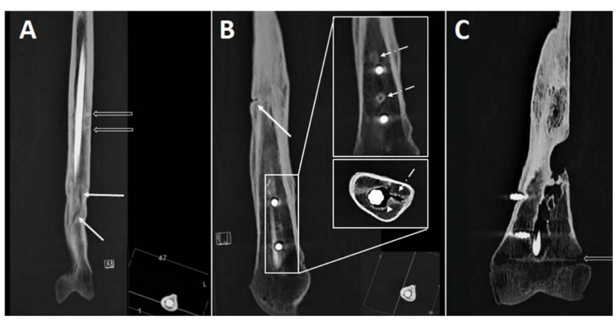

Figure 2 CT images of the right femur showing several findings that matched the missing person data: defects from the screws from an earlier external fixation (A and C, open arrows) and from a previous intramedullary nail (B, dashed arrows); contours of an earlier fracture/traumatic event (A and B, solid arrows) that were not related to the defect observed on the posterolateral portion of the distal shaft (C) and enlargement of the intramedullary space around the intramedullary nail with some sclerosis of the margin (B, arrowhead). CT: computed tomography.

dashed arrows), which confirmed the statements in the individual's medical records. The possibility that another intramedullary nail had been placed in the medullary cavity prior to the documented surgery was suggested by the widened intramedullary channel (Figure 2B, arrowhead). However, because this expansion of the channel was not uniform along the nail, it was impossible to exclude the possibility that the expansion was the result of nail movement in the medullary channel over several years, which was finally deemed most plausible.

The bone defect observed by visual inspection (Figure 1B) was noted in CT images as segmental bone loss in the anterior, posterior and lateral femoral shaft, with callus formation and sclerosis (Figure 2C). The finding was consistent with a comminuted fracture with loss of scattered fragments, as concluded after morphological analysis of the bone. However, in the images, it was possible to identify small metal fragments around the defect. Because the fragments were not contiguous with the nail or the screw-like lesions in the shaft, this finding was interpreted as bullet residues (Figure 3), which made the diagnosis of a GSW even more plausible.

The CT images revealed sclerotic callus formation with healed V-shaped fracture lines, located on the ventral femur, and above the segmental bone loss (Figure 2A and B, solid arrows). The lesion corresponded to the lateromedial bulging with periosteal reaction observed macroscopically on the anterior femoral shaft (Figure 1C). The different location and the absence of continuity between the two sites (which was not evident during the visual inspection of the bone) strongly suggested that they did not originate from a single lesion. Instead, these findings supported the idea that the callus formation with V-shaped fracture lines resulted from a separate fracture. This interpretation was confirmed in the medical records, which stated that no fracture line was seen in the vicinity of the gunshot bone defect. Although it was impossible to distinguish which lesion occurred first, as dating of antemortem fractures remains difficult and imprecise [34], the presence of the two defects aligned with the medical history and indicated two separate traumatic events to the femur.

Bone infection could not be completely ruled out. Sclerotic changes in the margins of the nail channel were noted. These could have originated from an infectious process in the area or from intramedullary nail motion over time. In addition to the sclerosis, other features common to fracture healing and chronic osteomyelitis should be considered during radiological assessment. These include cortical bone thickening and bone enlargement, with surface irregularity. However, cases of osteomyelitis also display a sequestrum (necrotic bone) and a sinus tract frequently, which were not observed in this case.

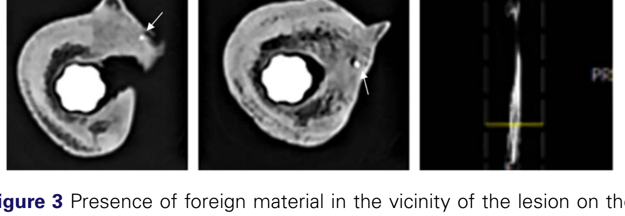

Figure 3 Presence of foreign material in the vicinity of the lesion on the posterolateral femur (arrows in A and B). This material was unrelated to the intramedullary nail and the multiple screws/screw defects. Therefore, this material was considered compatible with bullet residue. The location of the finding in the bone (C, horisontal line).

The imaging analysis was able to conclusively (i) identify signs of three different surgical procedures to the bone (two intramedullary nail fixations and one external fixation), (ii) support (with additional evidence) that the macroscopically observed defect in the bone could have been caused by ballistic trauma, and (iii) identify a separate traumatic lesion in the bone. If identification could not be achieved by primary identifiers, these features could have been considered sufficiently unique to strongly support, if not guarantee (with a matching biological profile), a positive identification.

With the radiological analysis, it was possible to confirm the different medical treatments performed on the femur and match the location and measurements of the intramedullary nail. With this imaging, it was also possible to reconstruct the most likely appearance of the first fracture to the bone, which was not reported or described in detail in the available medical records.

Discussion and conclusion

Identification is an essential and mandatory part of medicolegal and death investigations. When dealing with unidentified remains, it is crucial to carefully record, document and collect any evidence that could be important in the identification process, especially in cases where the preferred primary identifiers have limited applicability. That is, features other than DNA, fingerprints and dental records should not be neglected, but carefully collected, registered and documented.

Antemortem trauma is one of the anthropological features that can facilitate the presumption of identity and, in certain cases, provide sufficient information to make a positive identification. This approach is important both for comparative and reconstructive identifications, and many examples from medicolegal practice confirm its utility for identification purposes [14–16, 28, 29]. However, as experts state, before accepting such identifiers as the sole means of identification, the value of their evidence ("uniqueness") should be quantified, which is dependent on the affected population and context of death [3]. The same secondary identifiers can have decisive value for identification in closed disasters or in cases with a limited number of presumed identities, but very limited application and only informative value in open disasters or fatalities involving a high number of deaths. The likelihood that different persons in the same context of death could express the same feature must be considered during assessment of the corresponding traits in the reconciliation phase of identification. Another important aspect in the identification process is the type and quality of available ante- and postmortem data.

Antemortem trauma is a biological identifier that in some contexts, can lose its discriminatory value if not properly documented and reported. Because fractures are a global public health issue with an incidence rate of 2.3% (approximately 2 300 cases per 100 000 individuals) [35], the presence of antemortem trauma in unidentified remains, if treated as a binary value (present/absent), cannot be considered highly discriminatory for identification. The common nature of antemortem fractures in modern populations has also been observed in contemporary forensic collections or modern forensic cases [36–38]. The identificatory potential of antemortem trauma increases dramatically when data from the same source can be matched; i.e. by comparing the consistency in fracture patterns and characteristics (e.g. morphology and contour of the healed bone callus) between antemortem and postmortem images. The use of the morphological appearance of antemortem trauma for identification is widely accepted and considered valuable evidence in identity investigations. The same applies for cases in which surgical implants (often found with antemortem fractures) have a unique serial number that can be traced to the manufacturer or matched with the numbers in medical records [39–43]. However, identification in these cases can be complicated by other factors, such as primary healing, which can challenge fracture detection owing to the lack of visible callus formation [44, 45], time gap between when the antemortem records were created and the time of death and differences in imaging techniques, image quality and modalities. Additionally, antemortem images or medical records are not always available, which can necessitate the comparison of ante- and postmortem data from different sources and possibly decrease identification accuracy. Moreover, the implants used in fracture repair (e.g. bone plates) often have no traceable serial numbers [39]. These issues should always be considered when dealing with unidentified cases presenting with antemortem trauma. However, this should absolutely not limit or exclude the use of these findings for identification, even in situations involving a high number of deaths. This is especially important if decisive contextual information (medical history) on antemortem trauma not known at the time of analysis is retrieved at a later date.

To enhance the probability of a positive identification in cases showing antemortem trauma, it is crucial to gather extensive information from the analysed bone. That is, antemortem trauma should not be recorded by its presence and location only, but also analysed systematically, whenever possible. Features that today can be registered while analysing antemortem fractures include the type and form of a callus, presence of misalignment and the presence of pseudoarthrosis. Trauma severity, aetiology and mechanism, degree of repair and time elapsed from the traumatic event [46] are parameters that could be decisive for identification, but obtaining this information accurately remains a challenge. The guidelines of the American National Standards Institute/Academy Standards Board clearly state that "practitioners shall not provide a trauma interpretation for antemortem trauma except in cases that show identifiable features and patterning or radiographic evidence of identifiable foreign bodies" [47]. There remains a significant risk of misinterpretation, oversight and overextrapolation, and little evidence that accurate conclusions on antemortem trauma can be made satisfactorily. While we argue that future studies and technological developments should focus on developing new ways to extract and interpret information from antemortem bone fractures, this case demonstrates that currently, a comprehensive interpretation of trauma can be achieved using new technologies and a collaborative approach to injury analysis. We advocate for the routine combined use of anthropological and radiological methods, particularly CT [12, 48, 49], and close collaboration between anthropologists and radiologists. With the comparable, yet distinct, approaches to bone trauma interpretation, this collaboration can result in a more informative interpretation and reconstruction of the traumatic event and the subsequent healing process, compared with non-collaborative analysis [48, 50].

The presented case also highlights the complexity of understanding antemortem trauma, particularly in GSW. This case is unique in the number of specific features it presented. The likelihood that other individuals experienced the same traumatic events and surgical procedures was considered minimal. However, even in such a unique case, without radiological assistance, most of the observed and discriminatory features would have remained undetected through macroscopic analysis alone. Some of the above-mentioned features might also have gone unnoticed by radiologists, without posing the specific questions that arose after knowledge obtained from the medical records. Developing guidelines on how to analyse and record data, as well as compiling a list of data and features to be registered when evaluating antemortem fractures, is crucial for extracting complete and informative data without the aid of background information. Therefore, studies aimed at understanding traumatic and post-traumatic events from discrete traits of a healed fracture are essential. The same applies to developing and evaluating new imaging approaches that can reveal subtle features of healed fractures and methods to understand their correlation with the mechanism of trauma and the healing process. Currently, there may still be limitations in identifying discrete features in healed bone fractures, even with CT images. However, experience has shown that technological advancement will likely soon overcome these issues, as demonstrated by earlier challenges (e.g. the interference of metal artifacts in CT images that previously caused misinterpretations and missed diagnoses can now be reduced or removed with specific imaging modalities).

Even though the presented case was unique in its medical background and presentation, we believe that simpler cases of antemortem trauma can also provide valuable insights. Continued research and the development of standardised guidelines in this field will enhance our understanding and ability to extract meaningful information from cases with antemortem trauma.

Comment

To maintain anonymity in this case, although this was a report on identification, information on the biological profile, circumstances of the finding and other details from the case that could allow identification of the deceased by third parties have been intentionally omitted to guarantee and respect the rights of human integrity and dignity after death.

Authors' contributions

Anja Petaros conceptualised and designed the paper, performed an anthropological analysis, interpreted the data, wrote the original draft and edited the initial and final drafts. Eugénia Cunha performed an anthropological analysis, interpreted the data and edited the initial and final drafts. Maria Lindblom performed a radiological analysis, interpreted the data, provided resources and edited the initial and final drafts.

Conflict of interest

Eugénia Cunha holds the position of Editorial Board Member for *Forensic Sciences Research* and is blinded from reviewing or making decisions for the manuscript.

Compliance with ethical standards

Consent to participate and consent for publication were not applicable. This case report is derived from forensic practice, meaning that all procedures performed were part of routine medicolegal death investigation. The article does not reveal any information regarding the police investigations related to the case. The deceased person has no retrieavable living relative based on the official records in Sweden. The only relative reported in the official registry is unretrievable, probably deceased, but left the country and thus no information that could help localising the person can be obtained. Although this is a case report, the authors have attempted to ensure the anonymity of the subject as much as possible.

Disclosure statement

The authors report there are no competing interests to declare.

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