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Role of Orthopedic Implants and Bone Morphology in the Identification of Human Remains

ABSTRACT: When conventional methods of identification, such as visual recognition and dental comparison, cannot be used to identify a deceased person, it becomes necessary to consider alternative methods. The presence of an orthopedic implant in a body may assist identification if ante-mortem medical records are available for comparison. Another method of identification involves comparison of ante-mortem and postmortem radiographs. Eight cases are reported from Forensic Science SA where the presence of orthopedic implants and/or ante-mortem radiographs were used to try to establish identification. In six cases, positive identification was established, and in two cases with upper limb orthopedic implants, the bones remained unidentified. Manufacturers were unable to provide any information about the distribution and use of the implants that could be of use with identification, as there are no requirements in Australia for individual medical implants to be tracked. Such a system has the potential to aid postmortem identification if serial codes were etched onto implants that could then be traced to manufacturers, surgeons, and recipients of these devices.

KEYWORDS: forensic science, forensic anthropology, forensic radiography, medical device, skeletal remains

Forensic Science SA provides autopsy services to the State Coroner for South Australia, Australia, which has a population of *c*. 1.5 million people. Over 95% of the state's coronial autopsies are now performed at the Center. In addition to investigating the cause and manner of death, the Coroner is also responsible for establishing the identity of autopsied individuals. Such remains may, however, be difficult to identify for a number of reasons. In many cases, visual identification is possible; however, decomposition, facial trauma or disfigurement, incineration, and/or skeletonization may prevent this. While fingerprinting, dental identification or DNA analyses may be useful; comparison of radiographs of orthopedic implants and specific bony features may also be valuable ancillary techniques.

The current paper presents eight cases where orthopedic implants and radiographs were used as part of the investigation of possible identification. The cases are used to demonstrate the advantages and problems associated with such techniques, and to make recommendations for possible improvements in implant identification in the future.

Materials and Methods

The files of Forensic Science SA in Adelaide, South Australia, were examined over an 11-year period from May 1994 to April 2004 for cases where the identification of the deceased was complicated by processes of decomposition, skeletonization, and/or incineration, or by the finding of fragmented incomplete skeletons. In eight cases, the bones of the individuals were examined radiographically for individual features such as frontal sinus shape, healed fractures, and orthopedic implants. In six cases, this involved comparison of ante-mortem and postmortem radiographs. In the remaining two cases, orthopedic implants were present, but no ante-mortem records were available. The details of the cases are summarized below.

Case Reports

Case 1

A severely incinerated body of an adult female was located inside a burnt-out house. The mouth was edentulous and there was no jewellery or clothing on the body. Postmortem radiographs revealed a right hip prosthesis. These radiographs were compared with ante-mortem radiographs of the occupier of the premises, believed to be the deceased. The ante-mortem and postmortem radiographs of the prosthesis were found to correspond (Fig. 1). A calcified uterine fibroid was also noted in both pre and postmortem radiographs, and was considered to be identical in each radiograph, which further substantiated the identification. On the basis of these comparisons, the identification was established (a 77-year-old female). Death was attributed to incineration.

Case 2

Skeletal remains and clothing of an adult male were located in a forest. The postcranial remains were mostly complete, but much of the cranium was missing. Of note were two metal Harrington rods connecting the T4 to L3 vertebrae (Fig. 2). The teeth were unremarkable, with no evidence of dental restoration, thus preventing possible dental identification. Postmortem radiographs were taken and were compared with ante-mortem radiographs of the individual believed to be the deceased. Ante-mortem radiographs of the Harrington rods were available, as were skull radiographs showing the frontal sinuses (Fig. 3). Comparison with postmortem radiographs found correspondence between all

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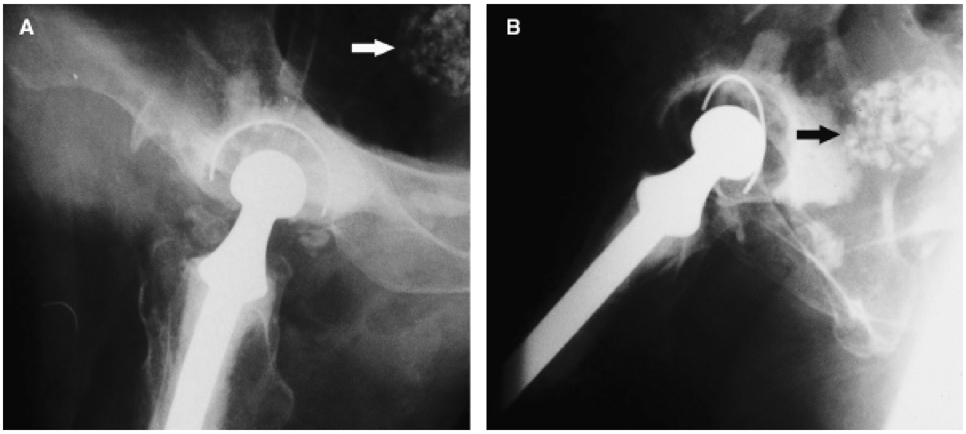

FIG. 1—*Ante-mortem (A) and postmortem radiographs (B) of a hip prosthesis in a 77-year-old woman in Case 1. Arrows mark the presence of a calcified uterine fibroid.*

features examined. On the basis of these comparisons, the identification was established (a 25-year-old male). The cause of death was undetermined.

Case 3

The dismembered, partially skeletonized body of an adult female was found in eight separate bags. The mouth was edentulous. Postmortem radiographs of a healed fracture of the right humerus were compared with ante-mortem radiographs (Fig. 4). On the basis of this comparison, the identification was established (a 47-year-old female). The cause of death was undetermined.

Case 4

The skeletonized body of an adult male was located in a paddock. There was extensive fracturing of the cranium and facial skeleton. Postmortem examination revealed an orthopedic plate

FIG. 2—*Ante-mortem (A) and postmortem radiographs (B) and postmortem photograph (C) of Harrington rods in the spine of a missing 25-year-old man in Case 2.*

FIG. 3—*Comparison of ante-mortem (A) and postmortem (B) frontal sinus morphology in the individual with the Harrington rods in Case 2. The absence of facial skeleton in the postmortem image is due to extensive ante-mortem trauma.*

fixed to the left ulna by six screws. Postmortem and ante-mortem radiographs were compared, which both showed penetration of the most distal screw of the plate through the shaft of the ulna (Fig. 5). Similarities were also noted between ante-mortem radiographs of recently fractured right metacarpals 2 years before death, and postmortem radiographs showing healed fractures in the same locations. On the basis of these comparisons, the identification was established (a 26-year-old male). Death was attributed to blunt craniofacial trauma.

Case 5

The decomposed body of an elderly female was found in her home. She had not been seen for at least 1 week. Her fingertips had decomposed, leaving no prints and there were no adequate dental records available for comparison with the remaining teeth. Ante-mortem radiographs showed unusual calcaneal spurs on the left heel that corresponded to postmortem radiographs (Fig. 6). On the basis of this comparison, the identification was established (an 80-year-old female). The cause of death was ischemic heart disease.

Case 6

The decomposed body of an elderly male was located inside a house. Neighbors reported not having seen the resident of the

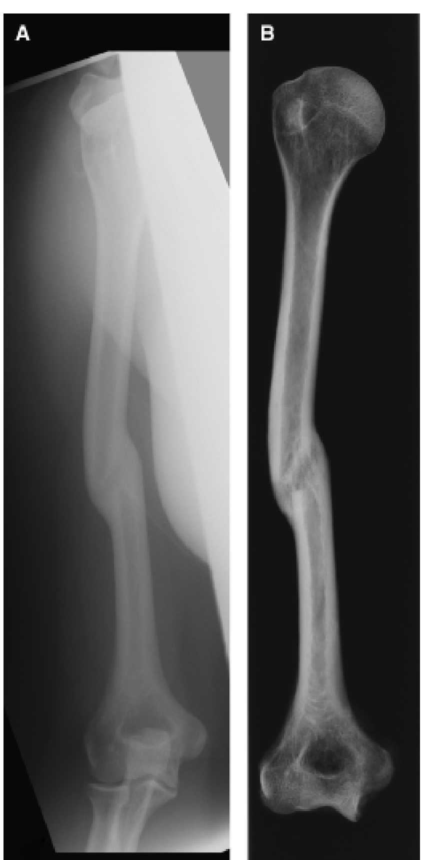

FIG. 4—*Ante-mortem (A) and postmortem radiographs (B) of a fractured right humerus in a 47-year-old female in Case 3.*

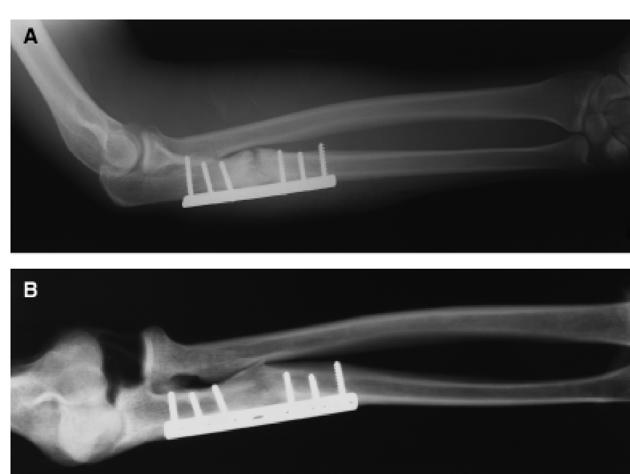

FIG. 5—*Ante-mortem (A) and postmortem radiographs (B) showing a plate in the left ulna of a 27-year-old male in Case 4.*

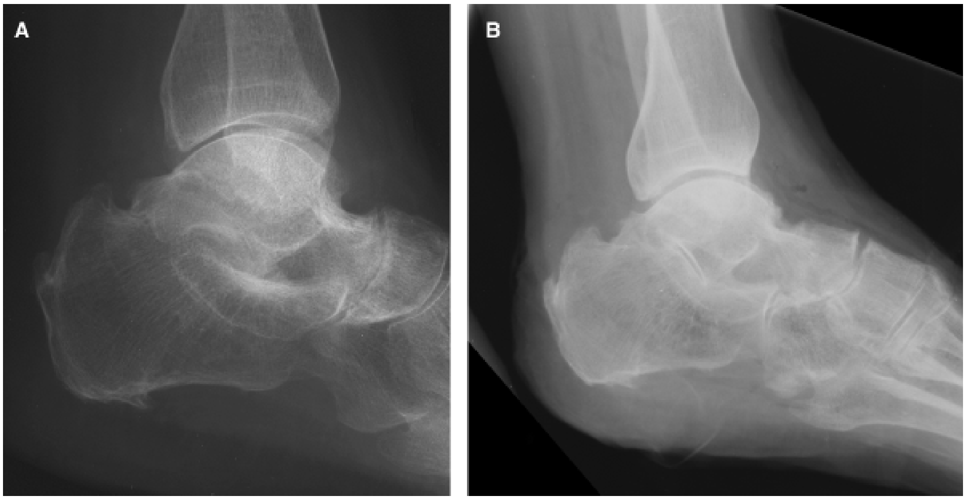

FIG. 6—*Ante-mortem (A) and postmortem radiographs (B) of the calcaneus in an 80-year-old female in Case 5.*

house for several days. The presumed deceased was believed to have no relatives in Australia, so no reference samples for DNA testing were sought. Dental records were unavailable; however, upon searching the house police located a package of medical radiographs bearing the name of the owner and resident of the house (believed to be the deceased). These ante-mortem radiographs included antero-posterior and lateral views of the skull, and a radiograph of the left elbow region. Postmortem radiographs were taken and compared with the ante-mortem radiographs. Corresponding features between the cranial radiographs included evidence of dental restorations to numerous teeth. Both ante- and postmortem radiographs of the left elbow showed irregularities of the distal posterior humerus and proximal ulna, including the olecranon process (Fig. 7). On the basis of these comparisons, the identification was established (an 82-year-old male). Death was due to hypertensive heart disease.

Case 7

A 100 mm long bone fragment consisting of two pieces of bone shaft connected by a metal plate was handed to police at Alice Springs. The bone was identified as a portion of human ulna (Fig. 8). The bone also had screw holes and bone modeling from a previous plate. The metal plate found with the bone had the lettering "Swiss," the numbers 248.06 and 1132, and had been manufactured by Mathys (Bettlach, Switzerland). Inquiries about the manufacture and use of the plate revealed that it was extensively used for fracture fixation (in both humans and nonhumans) and that there were no individual identifying features. The individual remains unidentified.

Case 8

A single fragment of human humerus was found on a coastal beach. At one end of the fragment was a metal plate affixed to the bone by a number of screws (Fig. 9). The metal plate had the lettering "Vitallium," and the number "5" between the third and fourth screws. Inquiries to the manufacturers revealed that there were no individual identifying features. An attempt to develop a DNA profile from the bone was unsuccessful. The individual remains unidentified.

In summary, six of the cases were identified based on various methods of comparison of ante-mortem and postmortem material. This included implant comparisons in one (Case 1), bone comparisons in three (Cases 3, 5, and 6), and implant plus bone comparisons in two (Cases 2 and 4), with additional ante-mortem healing fractures in two (Cases 3 and 4). In the remaining two cases (Cases 7 and 8), inquiries by the police and to the manufacturers of the implants were unsuccessful in obtaining identifying information, and the identification of these two individuals

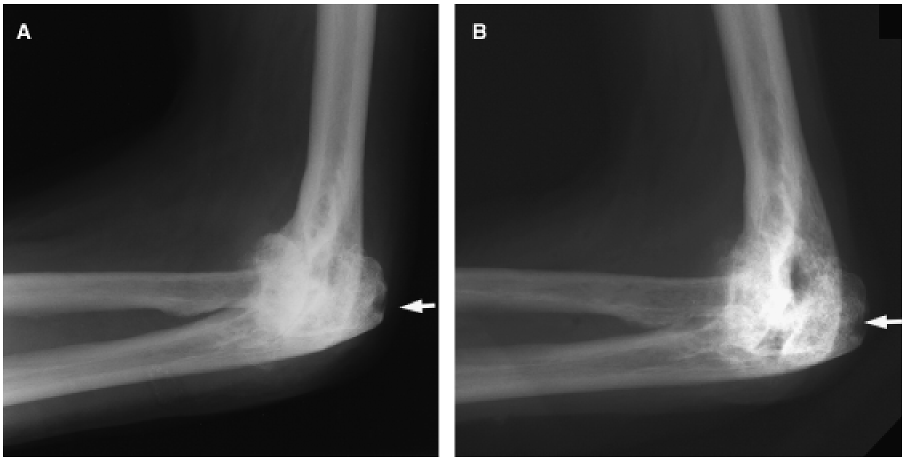

FIG. 7—*Ante-mortem (A) and postmortem radiographs (B) of the elbow of an 82-year-old male in Case 6. Arrows mark areas of similarity.*

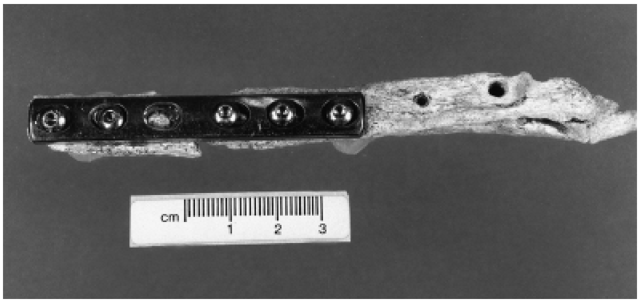

FIG. 8—*An orthopedic plate and fragments of ulna in Case 7. The additional screw holes indicate the presence of a previous plate.*

remains unknown. In addition, the skeletal material associated with these implants was extremely limited, consisting of fragments of long bone shafts only. This restricted the usefulness of an anthropological evaluation for sex, age, or other individual characteristics.

Discussion

Orthopedic or medical implants may be potentially useful for postmortem identification as they are relatively uncommon and usually contain individual identifying features, such as the type of device used and its anatomical location. Incinerated remains have been identified by both dental records and the presence of an orthopedic implant, or by an orthopedic device on its own (1,2), as was the situation in Case 1 of our report. In another study (3), the investigators were able to positively identify an individual based on the characteristics of an intraocular lens found in a decomposed body. However, the location of a medical implant with human remains does not always lead to identification, as in our Cases 7 and 8. The presence of three homicide victims in the series of eight reported cases is also noteworthy, as the bodies of homicide victims are often deliberately damaged or concealed in order to prevent identification, in addition to having sustained ante-mortem trauma. In these cases, radiological identification may be of vital importance if more usual methods of identification are not possible.

As part of an investigation into the usefulness of orthopedic implants for identification, a survey of manufacturers of orthopedic devices in the United States was conducted in 1994 (4), following a 1993 requirement in the United States to enable patient and device tracking. This requirement means that, in the United States, certain devices produced after March 1 1993 can be tracked to the manufacturer, physician, and patient (5). This tracking program is limited to devices that either sustain or support life, such as pacemakers; i.e. orthopedic devices such as bone plates are not tracked. In Australia, similar tracking programs for implanted medical devices are not yet in place, although they are currently being developed (6,7). However, such a tracking program would be of little use for the four implant cases reported here, as the devices were orthopedic and would not, therefore, be included in a register of life-supporting or sustaining devices. Despite the fact that more than 10 years have passed since the implementation of the device-tracking system in the United States, a review of the literature has found no information on the usefulness of the system for forensic identification. Such a study would be of considerable interest and relevance in the wake of recent situations of mass fatalities (for e.g., the South-East Asian Tsunami and Hurricane Katrina in the United States) where identification of deceased relied greatly on less commonly used methods due to the condition of the bodies. It would also be useful for the survey of manufacturers to be repeated, as it is probable that in the time since publication there have been new companies entering the market, or modifications in the device markings of existing companies. With the current trend in Australia of an increased percentage of the population approaching ages where advanced medical intervention will be required, it is likely that the number of people requiring orthopedic devices will also increase. This suggests that the use of tracking programs for orthopedic devices would greatly benefit the identification process should it become necessary.

With regard to identification using radiographs, numerous cases have been reported where comparisons of ante-mortem and postmortem radiographs of skeletal characteristics have assisted with identification. These have included general morphological comparisons (8–15), comparisons of trabecular architecture (16,17), and the location and identification of specific features, such as phleboliths (18) or surgical intervention (19). In recent years, computed tomography (CT) has also been used for this type of postmortem identification (20). A problem that may complicate this process is the automatic destruction of medical and dental records, including radiographs, after a certain time, as information that could be potentially useful to identify an individual may be lost.

Certain concerns have been raised regarding the validity of radiographic comparisons with establish identification. In our series of eight cases, three cases were found where identification was made by comparing ante-mortem and postmortem radiographs of apparently unique anatomical structures (Cases 2, 5, and 6), as opposed to a traumatic event such as a fracture of bone (Cases 3 and 4). In the first case (Case 2), the frontal sinuses (visible in antero-posterior cranial radiographs) were superimposed, and correspondence between the anatomical structures was seen. In this case, the identification was largely based on comparison of pre and postmortem radiographs of orthopedic implants, while the frontal sinus comparison was used as supporting evidence. In the second case (Case 5), irregularities of the calcaneus were compared between pre and postmortem radiographs. The identification of the deceased in this case was based on this comparison. In the third case (Case 6), ante-mortem and postmortem radiographs of the left elbow were compared. Overall similarities of size and shape were observed in addition to an irregularity of the olecranon

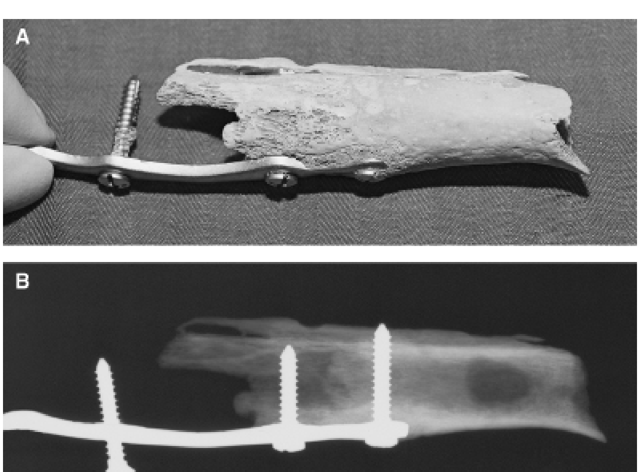

FIG. 9—*Photograph (A) and radiograph (B) of an orthopedic plate and fragment of the humerus in Case 8.*

area of the ulna. Combined with consistencies with pre- and postmortem dental radiographs, the identity of this individual was accepted. While we do not dispute the identifications that were made in the past using knowledge and expertise of the time, it will be interesting to explore this issue further once additional information becomes available, as this may assist in the identification of future individuals.

It appears that reliance on such comparisons of anatomical features is not as straightforward as it was originally thought to be. There is an assumption that these characteristics are unique, at least to the point where an identification can be made. However, until recently, no testing has been conducted to ascertain whether these assumed idiosyncratic features were in fact unique. *Daubert v. Merrell-Dow Pharmaceuticals Inc*. has emphasized the scientific validity of proffered scientific evidence for admission into United States federal courts and has given guidelines on what might constitute such validation. Before this, most courts in the United States used the 1923 Frye general acceptance test to determine the admissibility of novel scientific evidence (21,22). Thus, as a general rule, new methods of identification must no longer become accepted within the community before they are legally recognized; however, scientific reliability must be demonstrated. Such requirements are pertinent to the work of pathologists, dentists, radiologists, and anthropologists. Mistakes challenge the notion of reliability of methods and in this light a relatively recent reported example of misidentification of two firefighters who perished in the September 11, 2001, World Trade Center attacks is relevant. According to reports (23), an individual was identified on the basis of a congenital malformation of two cervical vertebrae as well as the presence of a distinctive piece of jewelery. The identification was accepted based on a comparison of ante-mortem and postmortem radiographs that were found to correspond. However, when DNA analysis was performed on the remains, it was discovered that the DNA results matched a different person, who also had a similar malformation of the same two vertebrae, and wore a similar piece of jewellery. This example highlights the important role of DNA investigation in cases of identification. If comparison reference samples for the unidentified individuals are available and a profile can be obtained from the remains, the value of DNA examination as a reliable identifier cannot be questioned. However, for cases where a DNA profile was unable to be generated (Cases 3 and 8), comparison samples were not available (Case 6), or no DNA sample was collected due to the fact that DNA technology was not yet widely used at the time (Cases 1, 2, 4, 5, and 7), other methods of identification still play an important role. The extent of the search to obtain reference samples from relatives to compare with the unidentified individual depends on the decision of the Coroner or Medical Examiner. If a circumstantial identification is acceptable, and the cause and manner of death are straightforward, it is often considered unnecessary to extend the search for relatives overseas, as was the situation in Case 6.

Following the *Daubert* case, research has been undertaken in an attempt to validate the previously held assumptions regarding the identifying characteristics of skeletal morphology. This includes the morphology of the frontal sinuses (10,22,24), cranial suture patterns (25), morphology and trabecular architecture of the bones of the hand (15), comparisons of chest radiographs (26), and trabecular morphology of the distal femur and proximal tibia (17). The minimum number of corresponding features that should be accepted for positive identification has also been addressed (17,25,27). While there is a lack of agreement on the minimum number of corresponding features, a primary consideration is the ruling out of any inexplicable inconsistencies between premortem and postmortem records (28).

The potential for identification based on the individual characteristics of a medical or orthopedic device is apparent. However, there are also problems with a lack of individual identifying features, such as a unique coding number. In addition, many orthopedic devices are used in both humans and veterinary practices, which can also complicate identifications. Currently, comparisons rely on the identity of the remains already being suspected, so that records can be obtained for relative matching. Placing a name, serial number, or some other unique marking on prostheses would greatly assist the identification process in providing an absolute indication of identity. These markings would provide an initial point of inquiry to the police, surgeon, or manufacturer that could then lead to identification of the deceased individual.

Another area to explore the possibility of unique markings concerns other devices such as dentures. Many individuals subjected to identification processes are edentulous. Although dentures may still be *in situ*, or near the body, matching dentures to an individual is unreliable due to the loose fit of the dentures to the edentulous mandible and maxilla. Marking dentures with the name of the owner or attending dental practitioner would also greatly assist in postmortem identifications. This would be particularly so in cases of mass disaster such as the recent South-East Asian tsunami, where foul play was not suspected, but a large number of bodies had to be identified as quickly and as efficiently as possible. Breast implants and artificial eyes could also be similarly coded.

The final issue to be considered regarding the identification of a deceased person based on the presence of an orthopedic implant or a distinctive skeletal or anatomical feature is that of the burden of proof of identification. In most countries, it is a legal requirement for the identity of a person to be confirmed before the body can be released for burial. Usually, this responsibility lies with the Coroner or Medical Examiner, who must accept the identification. This statutory responsibility allows the Coroner or Medical Examiner to arrange for steps to be taken to confirm the identification of a body. Under normal circumstances, this may consist of police taking statements from relatives or friends during a visual identification, police taking fingerprints from a body, and comparing it with records on file, analysis of DNA samples taken at autopsy, or dentists examining the teeth of the deceased and comparing them with ante-mortem records. Other methods may be acceptable at the discretion of the Coroner or Medical Examiner depending on the state of the body and the availability of ante-mortem material for comparison. This would include situations like those that have been reported above, or a circumstantial identification that may be the only avenue possible. Some common problems that arise with the identification of bodies in unusual circumstances are if only parts of a body are located (is the finding of an arm sufficient to conclude that a person has died?), or if a person is believed to have died but no body is recovered. Recent situations where this has been the case include the September 11, 2001, World Trade Center attacks, and the December 26, 2004, South East-Asian tsunami, where people are known or believed to have died but no part of them has been recovered. For these cases, it is now increasingly unlikely that positive identifications will be made for the individuals who have not yet been identified (29).

Coroners and Medical Examiners vary in the degree and certainty that they require to declare an identification. For example, in Cases 2, 5, and 6, comparisons of ante-mortem and postmortem radiographs, showing features thought to be unique, when the individuals were found in their residence under no suspicious circumstances, were considered to be sufficient. Other officials and perhaps the same officials, when faced with different circumstances, might require more rigorous identification methods such as fingerprint, dental, or DNA identification techniques. Distinctive physical characteristics (i.e., medical deformity or physical disease), marks and scars, radiologic features, and distinctive personal effects and clothes, which are suggestive but may not constitute positive identification in themselves, may give the official greater confidence in orthopedic implant and bone morphologic findings to permit identification. Ultimately, the authority and responsibility for the identification rest with an individual Coroner or Medical Examiner who will have his or her own personal opinion on the effort and information needed to declare an identification in a given case under the particular circumstance at the time. It must also be remembered that different Coroners or Medical Examiners, will have varying opinions on the level of proof acceptable for a positive identification.

In conclusion, while radiographs of implanted medical devices and unique bone characteristics may be crucial in establishing identity, as was demonstrated in the reported cases, significant problems remain. The validity of comparisons has been questioned and the lack of individual identifiers on orthopedic prostheses limits the identification of deceased individuals from medical records. Once an individual has been officially declared as missing, retention of all medical records including radiographs and dental records would be advisable.

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