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CASE REPORT

ANTHROPOLOGY; PATHOLOGY/BIOLOGY

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Radiological, Forensic, and Anthropological Studies of a Concrete Block Containing Bones*

ABSTRACT: Multidisciplinary forensic, anthropological, and radiological studies of bone fragments encased in a concrete block were carried out to determine whether or not the bones were human. Multislice computed tomography (MSCT) investigation was performed before the bones were removed from the concrete. MSCT study pinpointed the location of the bone fragments within the concrete block, which was helpful for their extraction and recovery, and identified most of their types and nature. Osteological study on dry bones provided more accurate identification of the bones and of their side. According to both methods, the human skeletal remains were compatible with those of a child, aged 8–13 years old, with a minimum height of 128 cm. Neither investigation identified sex or racial phenotype. Both studies identified the skeletal remains as consisting of two animal and five human bones. Furthermore, both methods revealed that the concrete completely encased bones, suggesting a secondary burial.

KEYWORDS: forensic science, anthropology, multislice computed tomography, bones, concrete

Interment in concrete is an unusual method of body disposal, rarely encountered (1). The often large, unwieldy size of the resulting cement blocks, combined with their substantial weight, makes them difficult to work with logistically. Freeing the decedent or the bones from the block requires careful thought and planning if important evidentiary information is to be preserved. The following case illustrates the importance of a multidisciplinary approach to bones interred in concrete, through collaboration by forensic pathologists, anthropologists, and radiologists, and it highlights the value of examination of such remains under optimum conditions. Transportation of the intact cement block to the medicolegal department is necessary for careful dissection, preservation of resultant evidence, and performance of complementary investigations, such as multislice computed tomography (MSCT) examination (1). The authors describe the multidisciplinary study of a concrete block containing skeletal remains.

Case Report

Case History

During house demolition in a French city, workers found bone fragments at the surface of a concrete block (Fig. 1). The local judiciary authorities requested that the block should be analyzed in the forensic department of Toulouse University Hospital. The police posed the forensic pathologist a number of classic forensic and anthropological questions: How many bones or bone fragments were contained in the block? Were the bones human or animal? If human, was it possible to determine the racial phenotype, sex, age, and stature of the deceased? How old were the bones? To answer these questions, multidisciplinary radiological, forensic, and anthropological investigations were carried out on the concrete block and the bone fragments.

Imaging Study

The CT examinations were performed at the Department of Radiology, Academic Medical Center, and University of Toulouse, France. The block of concrete, *c.* 42 × 37 × 17 cm in size (Fig. 2), was fully scanned with a multisection computed tomography (CT) scanner (Definition 64; Siemens Medical Systems, Erlangen, Germany) using the following parameters: 120 kV, 200 mAs, 0.75 mm section thickness, and 0.5 mm increments. The images were reconstructed according to both soft tissue and bone algorithms. The reconstructed spiral CT scans were transferred to a workstation (Leonardo; Siemens Medical Systems) for postprocessing. Maximum intensity projection (MIP) and volume rendering technique (VRT) three-dimensional (3D) reconstructions were performed. Based on axial CT scans, two-dimensional (2D) coronal and sagittal multiplanar reformatted (MPR) images were obtained. The images and 2D and 3D reconstructions were studied by a radiologist, who was also a medicolegal anthropologist, prior to removal of the bones from the concrete block.

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FIG. 1—*General view of the discovery site, showing the location of the concrete block containing bones.*

FIG. 2—*Superior view of the concrete block.*

Virtual Anthropological Study

To determine whether the bones were human or animal, we calculated the medullary index. This is defined as the ratio of the smallest diameter of the medullary shaft to the diameter of the diaphysis at the same level (2,3). The major drawback of this technique is that it requires a relatively well-preserved long bone. In humans and anthropoid monkeys, the medullary cavity is narrow compared with the transverse diameter of the bone. In the human adult, the average medullary index is 0.45; in the human fetus, it ranges from 0.15 to 0.48 and in the human child from 0.37 to 0.50. In present-day domestic animals, the index is greater than 0.50: on average 0.55 for pigs, 0.66 for dogs, and 0.75 for chickens.

To determine the type of bone, the racial phenotype, sex, age, and stature of the deceased, textbooks of anatomy and anthropology were used (4–8). Age and stature were estimated by measuring long bones and applying conventional formulas (4–8). The postmortem interval (PMI) could not be determined by MSCT.

Anthropological Study on Dry Bone

The bones were carefully extracted from the concrete block for anthropological study, guided by the MSCT images and using ordinary hammers and chisels. After complete extraction, the bones were partially restored and analyzed.

To determine whether bones were human or animal, we applied accepted macroscopic criteria used in archeology and anthropology. Animals have much thicker, more compact bone than humans (9). Their trabecular units are a different size and shape, and this gives a heavier and more solid appearance than comparatively more porous and lighter human bones. The line between the spongy and the compact part of animal bone is also less distinctive than in human bones. Their outer/inner surface is often smoother and gives the examiner a feeling of unbreakable solidity.

To determine the type of bone, the racial phenotype, sex, age, and stature of the deceased, textbooks of anatomy and anthropology were used (4–8). Age and stature were estimated by measuring long bones and applying conventional formulas (4–8).

To determine the PMI of the bones, the best-preserved long bone was transversely sectioned and the external and internal walls of the shaft were grossly examined (10). Ultraviolet-induced fluorescence analysis was also carried out (11).

Results

Virtual Anthropological Study

To determine whether the bones were animal or human skeletal remains, the medullary index was measured on the best-preserved bone (left femur). This was found to be between 0.42 and 0.47, which suggests a human origin (Fig. 3) (2,3). Seven bone fragments were individualized. One was at the surface of the block and seemed to be part of a diaphyseal long bone whose type and nature could not be determined by MSCT. The bones within the block were assessed by the differentiation of cortical and trabecular bone from the surrounding concrete. Because concrete and skeletal densities were similar, the presence of trabeculae served as a criterion to differentiate bone from the concrete matrix. No epiphyseal areas were visualized on the long bones, so the articular surfaces could not be evaluated. This observation could be explained by the age of the deceased (immature subject with loss of the epiphyses because of secondary burial) or by taphonomic processes during a primary burial. Six fragments were interred within the concrete block: five fragments of long bones and one of a flat bone. The type of bone was identified by the morphology of the long axis and the short axis. Of these six fragments, one was an unidentified fragment of diaphyseal long bone of animal origin and five were recognized as human skeletal remains:

- one left proximal femoral extremity with an almost complete diaphyseal fracture (Fig. 3),
- one right proximal femoral extremity with only the upper third of the diaphysis (Fig. 4),
- one tibial diaphysis (Fig. 5),
- one unidentified human long bone diaphysis (Fig. 6),
- one portion of a coxal bone (periacetabular region) (Fig. 7).

Age was assessed from the best-preserved bone (the left femur) (Fig. 3). Its total length was 32 cm, compatible with an immature individual, with an estimated minimum age of 8 years (4–7). This age was also compatible with the absence of the femoral head and of the greater or lesser trochanter (4–7). Maximum age was calculated based on minimal age of fusion of the femoral secondary ossification centers and fusion of the three parts of the innominate, and was estimated at 13 years (4–7).

Height was calculated based on the measurement of minimum diaphyseal length. On MPR reconstructions, this was 25.3 cm, corresponding to a minimum height of 128 cm (5,8).

The nature of the bones and the skeletal immaturity did not allow determination of sex and racial phenotype. The human skeletal remains presented no sign of tumor, chronic infection, or

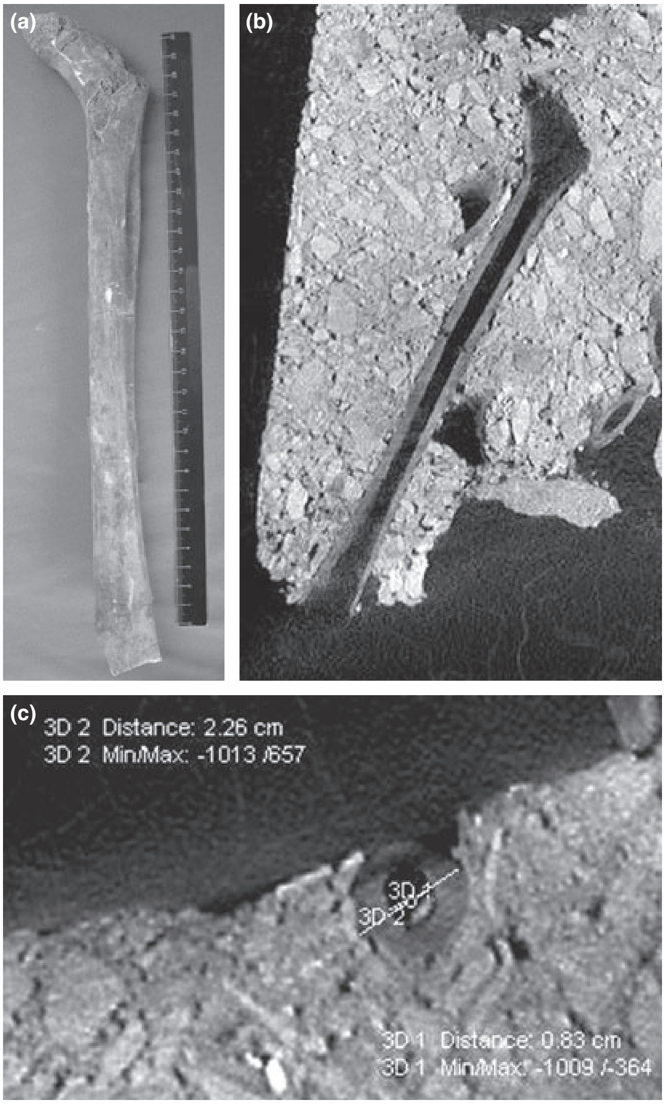

FIG. 3—*Left femur. (a) Dry bone. (b) 2D MPR reconstruction. (c) Transverse cut of the diaphysis; calculation of the medullary index. MPR, multiplanar reformatted.*

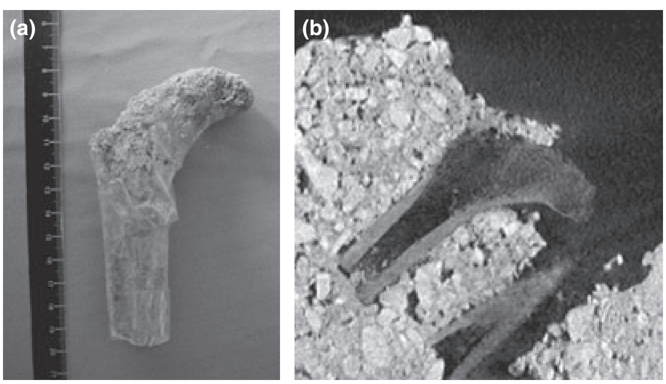

FIG. 4—*Right femur. (a) Dry bone. (b) 2D MPR reconstruction. MPR, multiplanar reformatted.*

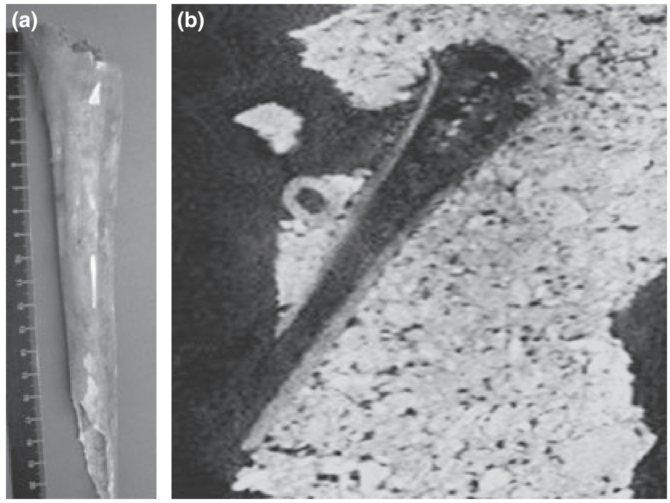

FIG. 5—*Left tibia. (a) Dry bone. (b) 2D MPR reconstruction. MPR, multiplanar reformatted.*

periostitis. There was no thickening of the cortex or bowing, suggesting premortem trauma or healed fracture, and no visible sign of trauma or malnutrition (e.g., Harris lines). The various bones lay randomly within the block, with no anatomical joint connections, and the concrete closely surrounded the bones, and no soft tissue was visible around them (Fig. 8).

Unfortunately, 3D VRT reconstruction of each bone was not possible because of the difficulty of segmentation and electronic removal of the bones from the concrete because of the latter's high density.

Anthropological Study on Dry Bone

Macroscopic examination confirmed the imaging findings. The extraction of the bones was difficult, and several bones fractured during their removal from the concrete. No ante- or perimortem trauma were visible, and no periosteal reaction could be seen at the surface of the various bones. Concerning a possible secondary burial, macroscopic examination of the extremity of some bone fragments showed brown traces suggesting soil.

Determination of the origin, type, and side of the bones was more accurate and easier than on MSCT reconstructions. At the surface of the block, one unidentified fragment of diaphyseal long bone of animal origin was observed. Within the block, we identified:

- one left proximal femoral extremity with an almost complete diaphyseal fracture (Fig. 3),
- one right proximal femoral extremity with only the upper third of the diaphysis (Fig. 4),
- one left tibial diaphysis without the tibial tuberosity (Fig. 5),
- one left humeral diaphysis (Fig. 6),
- one portion of a left coxal bone (periacetabular region) (Fig. 7),
- one unidentified fragment of diaphyseal long bone of animal origin.

The nature of the bones and the skeletal immaturity did not allow determination of sex and racial phenotype.

Classically, determination of the PMI of bones is based on the external and internal morphological modifications of the bones secondary to alteration of the bone matrix. Initially, bones continue to have a greasy appearance. Loss of protein and blood product content over the centuries results in an increasingly "chalky" texture and appearance (10). The bones in our case had such a texture and appearance. No ligament or soft tissues were visible. Many techniques have already been described for determination of the PMI

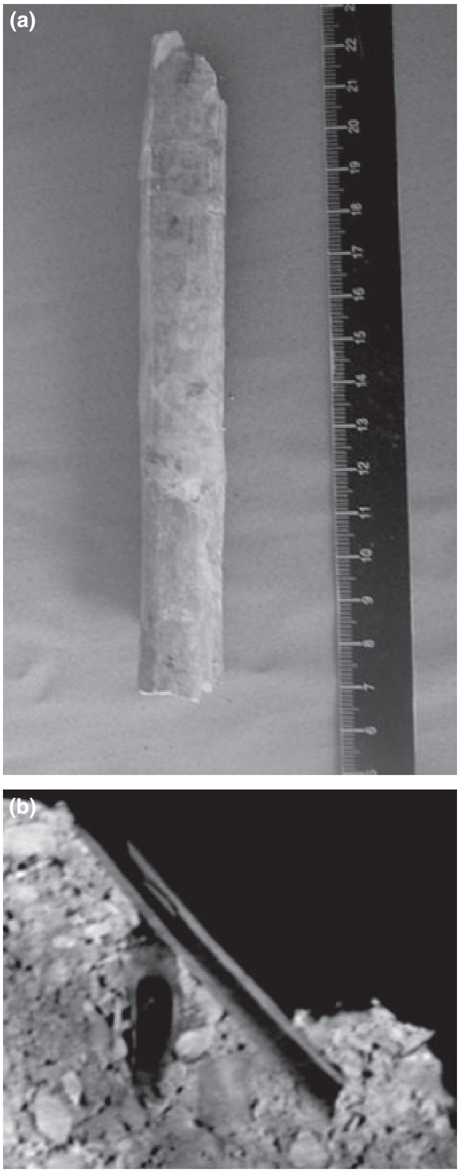

FIG. 6—*Left humerus. (a) Dry bone. (b) 2D MPR reconstruction. MPR, multiplanar reformatted.*

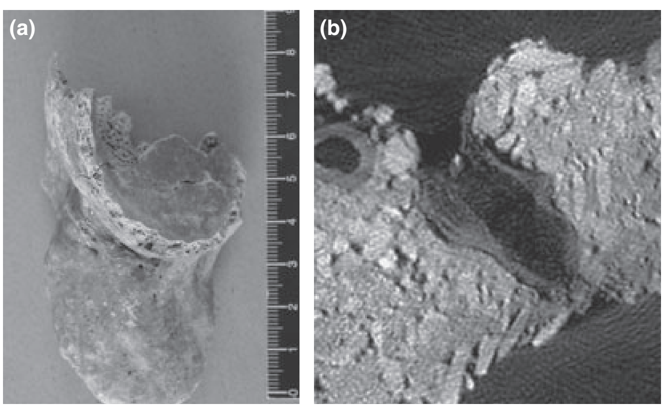

FIG. 7—*Portion of a left coxal bone. (a) Dry bone. (b) 2D MPR reconstruction of the partial coxal bone. The fragment was identified by visualization of the acetabulum. MPR, multiplanar reformatted.*

FIG. 8—*Superior view of the block of concrete containing bones, 3D VRT mode. The bones are visible within the concrete and are not in an anatomical position. VRT, volume rendering technique.*

FIG. 9—*Transverse cut of the diaphysis of the left tibia. Absence of ultraviolet fluorescence.*

of human skeletal remains (12). We used ultraviolet fluorescence. The inherent fluorescence pattern of the cut bone surface is progressively lost. Fluorescence diminishes after 100 years PMI, with concentric loss of fluorescence up to 800 years after death. The absence of fluorescence, as in our case, was in favor of a bone age of more than 100 years (Fig. 9).

Summary of Anthropological Studies on Virtual and Dry Bones

A mixture of two animal and five human skeletal remains was identified within and at the surface of the concrete block. The human remains consisted of one left and one right femur, one left tibia, one left humerus, and one portion of a left coxal bone (periacetabular region). The bones were poorly preserved and considerably damaged, without epiphyses or cartilage at their proximal or distal extremities. The human skeletal remains were compatible with those of a child, aged 8–13 years old, with a minimum height of 128 cm. Sex determination was not possible, and racial phenotype could not be determined. The concrete completely encased the bones, without any space indicating that the bones could have been placed in the block after complete skeletonization. Some extremities of the bones had brown traces suggesting soil. This suggested a secondary burial: secondary removal of the bones from the first (primary) burial after complete putrefaction and skeletonization of the deceased. The age of the bones was estimated at almost 100 years. The most likely explanation for the presence of human skeletal remains within the concrete block was secondary removal of bones discovered in a primary burial (soil), but not reported by a previous owner of the house in which the bones were found. This situation has been described as frequent (13).

Discussion

Forensic cases involving paving materials require special equipment and technical procedures (14). Exhumation of a concealed body is always a complex process, best handled by a team of experienced death investigators. Use of heavy construction equipment for exhumation carries the risk of creating artifactual injuries. In general, tools such as backhoes should be avoided. When the body is encased in paving materials, heavy equipment is necessary for handling the mass and resistance of the material. The effects of body disposal in this way may include preservation of the body and its identifying marks, preservation of trace evidence and toxicology specimens, and the creation of a negative cast of the body (1). In several cases, the cement provided a mold of evidentiary value that could be used to identify the decedent by fingerprints or other means. On the other hand, removing the body from the concrete may produce taphonomic changes. The hydration of cement is exothermic (1). As concrete cures, it may reach temperatures up to 79°C for the first few days, resulting in accelerated decomposition. After curing is finished, the concrete may insulate the body from heat and air. In addition, damp cement is highly alkaline. Thus, encasement in concrete may slow decomposition in some circumstances. Decedents encased in cement or mortar may be discovered by chance, following the confession of the perpetrator, through an anonymous tip, or during investigation of a missing person report (1). It is essential to examine the remains under optimum conditions, transporting the heavy cement or concrete blocks to the medical examiner's office for evaluation (1,14). This allows MSCT investigation to be performed before disturbing the cement encasing the decedent or the bones, so that efforts to free them can be directed away from the remains. A multidisciplinary team approach is essential and involves the extensive use of consulting professionals in the disciplines of anthropology and radiology (1,14). This allows the collection of possibly valuable evidence, such as concrete molds, artifacts, and trace evidence. Consultants in the disciplines of anthropology, odontology, and radiology are particularly helpful in establishing the age of the decedent and the presence of preexisting trauma, as may be seen in cases of child abuse (14).

Soil samples containing particular archeological materials or fossilized bones have been studied by MSCT to better characterize their contents (15–18). It has already been reported that MSCT has a potentially important role as a nondestructive imaging test for skeletal remains that are embedded in their soil matrix. However, this is the first time, to the best of our knowledge, that MSCT has been used to study the interior of a concrete block for an anthropological purpose. This case shows that MSCT is useful for the forensic pathologist and the forensic anthropologist who have to study skeletal remains embedded within a concrete block. MSCT was able to differentiate human and animal remains but in our case, dry bone study identified more accurately the type of bones and their sides than MSCT. MSCT was able to identify human skeletal remains as immature bones and permitted the calculation of minimal age and stature of the deceased. No bone trauma was revealed by paleopathological study either by MSCT or by dry bone examination, and both techniques identified a secondary burial. It was not possible to create VRT 3D reconstructions of each bone, because of the high concrete density which made impossible the surface morphology analysis that can be helpful in such cases. However, 3D MIP and 2D MPR reconstructions, although of less than optimal quality, revealed details that permitted an exhaustive bone analysis. MSCT investigation clearly has many advantages, namely the possibility of noninvasive in situ study, without risk of damage to the bone. In this case, the physical extraction of the bones was difficult and several bones fractured during their removal from the concrete. This was because of the vibration of the hammer and the poor state of preservation of the bones.

Multislice computed tomography techniques could not estimate the PMI of the bones or detect colorimetric differences at the surface or within the bones. Classically, determination of the PMI of bones is based on their external and internal modifications secondary to alteration of the bone matrix (10). Despite the fact that the majority of estimates continue to be based on morphological criteria, the inherent inaccuracies of this method reinforce the requirement for a reliable and accurate method for estimating the time since death in human skeletal material. Many complementary techniques have already been described for PMI estimation of human skeletal remains, including microscopic and analytical methods (11,12,19–27). The blue-white fluorescence of the cut diaphyseal bone surface seen under UV light, as performed in this case, is said to alter with time (28,29). The absence of fluorescence, as in our case, was in favor of a bone age of more than 100 years. French penal law provides for prosecution up to 10 years after the crime. Once this time limit has passed, no penal prosecution is possible. As the PMI of the bones discovered in this case was longer, no further analyses were performed.

This report offers an alternative method for bone study by using CT to distinguish bone and concrete. It is a preliminary attempt to scan skeletal remains embedded in a concrete block, in such a way as to prevent disintegration of fragile bones and joints. This approach seems promising and may be useful in rescuing qualitative and quantitative data that could sometimes be irreversibly lost during removal from concrete.

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