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CASE REPORT

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Virtual Autopsy and Forensic Anthropology of a Mummified Fetus: A Report of One Case*

ABSTRACT: A jar containing the mummified body of a fetus was found in a bush near a building. Full-body multislice computed tomography (MSCT) was performed prior to autopsy to study the bones and internal organs. Age was estimated by measuring femoral and tibial lengths and examining the temporal and occipital bones. The results were then compared with the autopsy and histopathological findings. MSCT was superior to autopsy for examination of the bones and internal organs. Autopsy was difficult because of the fragility of the dried corpse. MSCT determined the gestational age of the fetus and excluded skeletal abnormalities. Estimated age was similar with the two methods used. However, the major advantage of MSCT was rapid measurement of bones or anatomical regions which are difficult to examine during autopsy and which required specific preparation for further anthropological study. This case report illustrates the possibilities offered by MSCT for studying mummified bodies, even fetuses.

KEYWORDS: forensic science, fetus, computed tomography, anthropology, mummy

Dead human and animal tissue can, because of natural conditions or artificial processes, escape postmortem decay partially or even completely (1,2). This process called mummification derives linguistically from the Persian word "mum" or "mom," which means beeswax. Natural mummification may occur under contrasting climatic conditions: the alpine/artic process of freeze-drying, which requires sufficient air flow to sublimate body water, preservation in northern European peat bogs where acids interfere with enzymatic soft tissue decomposition, or the mummification that can occur in the hot and arid environment of deserts. Radiologic imaging of bodies preserved from ancient times, such as mummies, is currently defined as paleoradiology (3).

We examined a naturally mummified fetus using multislice computed tomography (MSCT). This instrument enabled us to determine gestational age, make an exhaustive skeletal study of the fetus and exclude malformations.

Materials and Methods

Case

A jar containing the body of a fetus was found in a bush near a building. The body was mummified and unidentified (Fig. 1). Forensic autopsy was ordered.

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Imaging Study

Full-body MSCT was done in the radiology department on the day the corpse was recovered. Axial MSCT was performed with 16×0.75 mm collimation on a Sensation 16 unit (Siemens,

FIG. 1—*Anterior view of the fetus at autopsy. The entire body is mummified. No traumatic injury is visible. Presence of a penis.*

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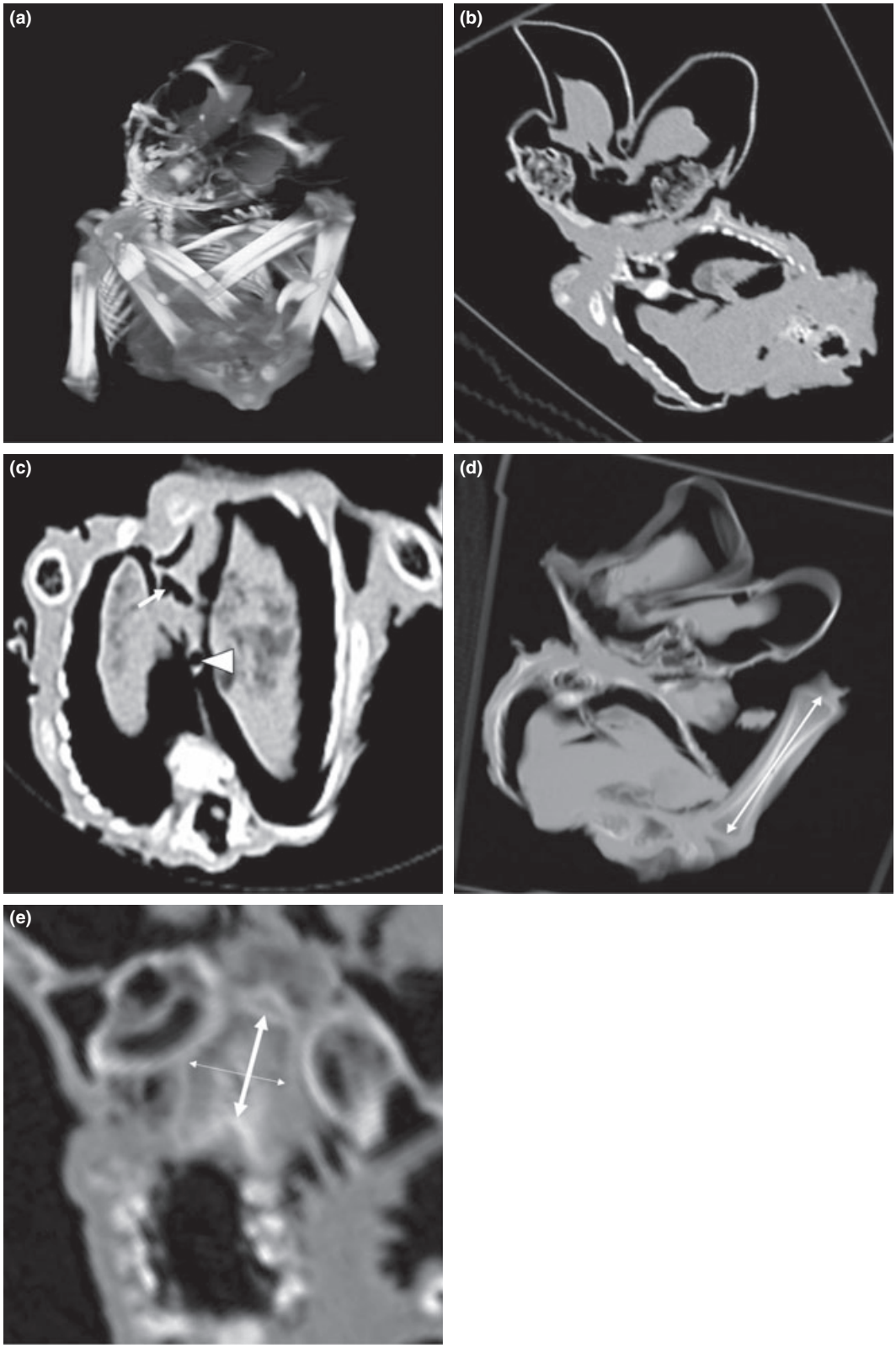

FIG. 2—*Postmortem skeletal MSCT study. (a) Volume rendering technique reconstruction (bone filter), anterior view of the fetus: no skeletal malformation or injury is visible. (b) Multiplanar reconstruction (MPR) frontal two-dimensional (2D) reconstruction: visualization of the collapsed parietal bone and air within the right lateral ventricle. Presence of air around both lungs which have a nonaerated appearance. (c) Axial image of the chest: presence of air within both major bronchi and the esophagus; both lungs have a nonaerated appearance. (d) MPR 2D reconstruction: measurement of the length of the left femur. (e) MPR 2D reconstruction: measurements of the length (wide arrow) and the width (thin arrow) of the pars basilaris of the occipital bone.*

Erlangen, Germany). This acquisition was obtained in 10 min. Two filters were used for axial image analysis: one for bone analysis and one for soft tissue analysis. Based on osteometric criteria used for estimation of gestational age, virtual anthropological study was carried out. Tibial and femoral lengths were measured (4–6) and age was estimated by examination of the temporal and occipital bones (4,7). Two-dimensional (2D) and 3D reconstructions were obtained on a Leonardo workstation (Siemens). Two-dimensional reconstructions were produced using multiplanar reconstruction (MPR). 3D reconstructions were produced using the volume rendering technique and maximum intensity projection modes. The images were interpreted by board-certified radiologists.

Autopsy and Histopathological Studies

Autopsy was performed by board-certified forensic pathologists. All three body cavities (cranium, thorax, and abdomen) were examined. The lengths of the tibia and the foot were measured. Histopathological examination was performed after fixation in 10% formalin and decalcification with nitric acid. The results of the different investigations were compared.

Results

Virtual Autopsy and Anthropology Using MSCT

Virtual Autopsy—Multislice computed tomography found no bone fractures due to injury (Fig. 2*a*). The head was deformed because of the collapse of both parietal bones (Fig. 2*b*). Air between the skull and the cerebral hemispheres and the prominence of the ventricles was clearly visualized, caused by volume loss. The cerebral hemispheres, cerebellum, pons, medulla oblongata, and spinal cord could also be seen. In the thorax, the lungs appeared tiny and nonaerated. The trachea and both major bronchi were visible and had air-filled lumens (Fig. 2*c*). The esophagus was visible from its proximal to distal extremity, filled with air. The heart was seen but the four cardiac chambers could not be identified. The stomach was filled with air. The liver and a penis were visible. Other internal organs were not identifiable because of loss of spontaneous contrast.

Virtual Anthropology—The tibial and femoral lengths were measured on 2D MSCT reconstructions: length of both femurs was 42 mm and of both tibias 40 mm, corresponding to a gestational age of 23 weeks (4–6).

Two-dimensional MSCT reconstructions of the pars squama and the pars basilaris of the occipital bone were performed and measurements were carried out. The pars squama measured 28 mm in height and 32 mm in width, consistent with a gestational age of 22–24 weeks (4). The pars basilaris measured 8.5 mm in length and 8.3 mm in width, in agreement with a gestational age of 22–26 weeks.

In the external ear, both external auditory canals were well defined and normally aerated. In the middle ear, the malleus, stapes, and incus were present with an intact ossicular chain (Figs. 3*b* and 3*c*). The footplate of the stapes was visualized within the oval window (Fig. 3*c*). The tympanic cavity was normally aerated.

In the inner ear, MSCT showed that the cochlea and vestibule had reached full adult size (Fig. 3*a*). A continuous shell of bone surrounded the cochlea. The lateral, posterior, and superior semicircular canals were visible. The labyrinthine segment of the facial nerve canal and the pyramidal process were well developed (Fig. 3*d*). The internal auditory canal was well defined. The subarcuate space remained prominent. Both vestibular aqueducts were visible but not the cochlear aqueducts (Fig. 3*b*). These imaging findings suggested a gestational age of 22–24 weeks (7).

External Inspection

The body was a completely mummified male fetus, with dry brown skin. The dried skin was unremarkable and no external injury was noted. The distal extremity of the umbilical cord was present. It was not possible to determine whether it had been cut or torn. The placenta was missing. The fetus was in a curled position. Each foot had five toes and each hand had five fingers. No abnormality of the upper and lower limbs was seen. The skull bones were collapsed. No malformation of the face was observed. There was no evidence of injury on the posterior part of the body. The anterior part of the body was inaccessible because of the fetal position. Examination of the genital region was difficult, but a penis was observed.

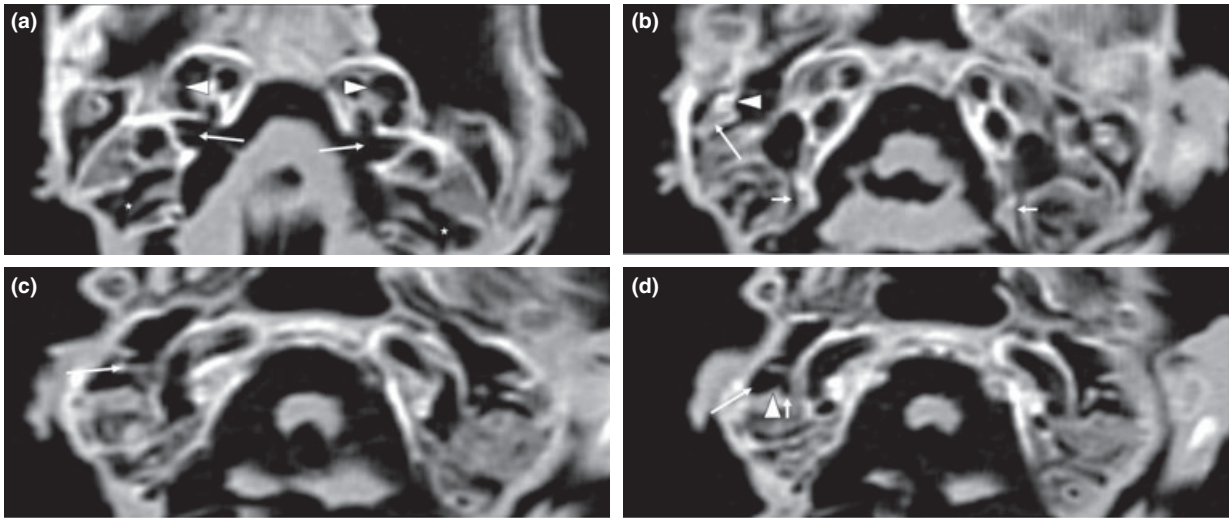

FIG. 3—*Postmortem skeletal MSCT study, axial images of the temporal bones (from cranial to caudal). (a) Both cochleas (arrowheads), vestibules (arrows) and the internal auditory canals (asterisks) are seen. (b) Right temporal bone: the incus (large arrowhead), malleus (arrow) and both vestibular aqueducts (small arrowheads) are visible. (c) Right temporal bone: stapes (arrow) within the oval window. (d) Right temporal bone: the pyramidal process (arrowhead), the facial nerve recess (small arrow), and the sinus tympani (large arrow) on the posterior wall of the tympanic cavity are seen.*

Autopsy and Histopathological Examination

Autopsy was difficult because of the dried consistency of the corpse. It was very fragile and the anterior part of the body could not be freed without breaking the upper and lower limbs.

The length of the tibias was 40 mm (Fig. 4*a*), corresponding to a gestational age of 23 weeks (4,8). The length of the foot was 35 mm, giving an estimated gestational age of 21–22 weeks. The tibia had endochondral ossification, with the epiphyseal plate visible at the upper and lower third. The periosteum was ossified. The spongy bone consisted of plates (trabeculae) and bars of bone adjacent to small irregular cavities that contained red bone marrow. The striated muscle had well-defined striations. The cell nuclei were cylindrical and peripheral. The epidermis was keratinized. The dermal papilla, sebaceous glands, and hair papilla were visible.

Endochondral ossification was noted in the temporal bone (Fig. 4*b*). The ossicular chain was visible, surrounded by aerated mesenchyma. The facial nerve was also visible. The three semicircular canals were present. Ossification had begun in the cochlea, which had only a single turn. The cochlear and vestibular aqueducts were visible.

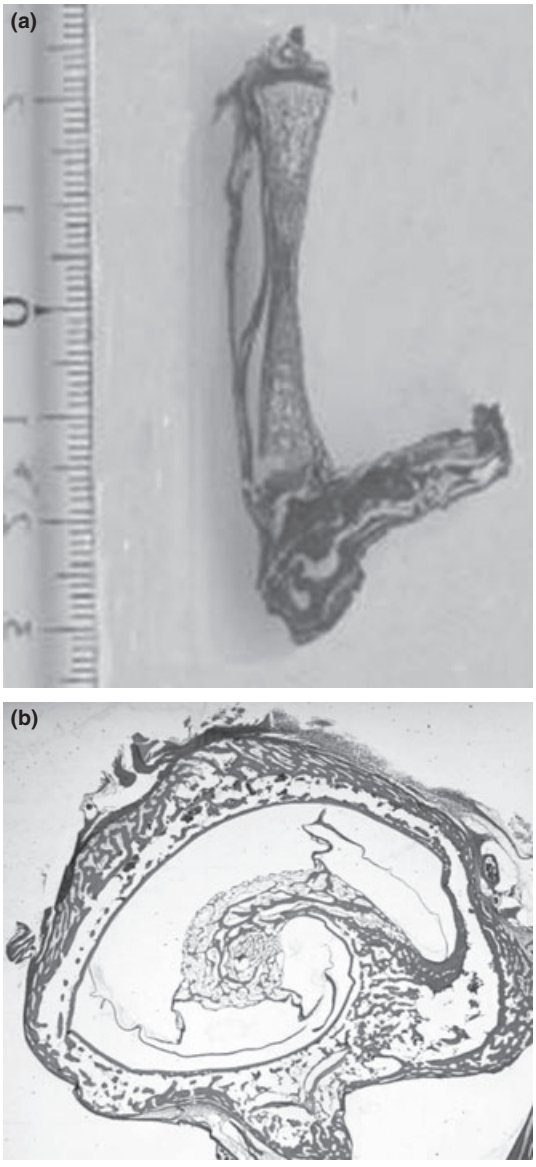

FIG. 4—*Postmortem histological examination. (a) Anatomo-pathological longitudinal slice of the right leg: measure of the lengths of the right tibia and foot. (b) Anatomo-pathological slice of the right vestibule. Ossification had begun in the cochlea, which had only a single turn.*

Histological analysis confirmed that fetal growth (osseous, vestibulocochlear, cutaneomuscular) was at least 20 weeks (9,10). More precise estimation was not possible because of maternofetal factors (drug addiction, metabolic disorders) which may interfere with fetal development.

Discussion

In the naturally frozen mummies of the High Andes, postmortem changes have been recently evaluated using nonhelicoidal computed tomography (3). The authors showed a decrease in size of soft tissue compartments resulting from loss of water during the natural process of mummification. The overall state of preservation of these bodies remains excellent and allows accurate identification of the internal organs and soft tissue pathologies. In our case, visualization of bones and organs was excellent with MSCT. Skeletal malformations were excluded. Examination of the head and the thorax excluded a major disease condition. In the abdomen and pelvis, organs such as the stomach and liver were clearly seen. Other anatomical structures could not be differentiated because of loss of contrast due to mummification and the absence of fat, which is a natural contrast agent on MSCT images. Autopsy was difficult because the subject was both mummified and a fetus. Full examination of all organs was not possible because this would have required complete destruction of the body, which is unethical.

In forensic medicine, estimating gestational age is an important issue, not only to determine the cause of death but also to assess viability, to diagnose pathological conditions that could affect growth and to differentiate between aborted fetuses or stillborns and legal and illegal abortions (11). Gestational age is determined by estimation of fetal developmental age based on skeletal growth. With the development of prenatal ultrasonography, several charts are now available for complete fetuses or the ossified parts of developing bones (5). In forensic practice, charts can be useful in real anatomical conditions, however radiographic methods have to be applied when skeletal preparation is impossible or undesirable (11,12). Radiographic measurements of the ossified shafts of long bones can also be used in real anatomical conditions, after applying a correction factor for radiological values (11). Fetal age can be measured by crown-rump, fetal and femoral length, by biparietal diameter, or skeletal maturation. Fetal parts and soft tissues, if extrauterine, are sufficiently small for radiological magnification not to be a major problem in view of the rather wide range of standard deviations for the various fetal measurements, most of which nowadays are based on real-time intrauterine measurements by ultrasonography. Intrauterine fetuses imaged on radiographs are magnified but correction factors can be applied. MSCT gives an isotropic image and does not deform the anatomical reality. This is important because measuring lengths of long bones on 2D reconstructions gives the anatomical length directly, without using correction factors (13). Sometimes, as in the present case, radiographic measurement of long bones on plain X-rays appears difficult or impossible because the bones are superimposed due to the position of the body. With a single scan, MSCT determined the length of most the long bones. Furthermore, it enabled skeletal and internal examination to deter mine whether major abnormalities were present or not.

A supplementary method of assessing gestational age was used in this case: examination of the temporal and occipital bones. These

bones have already been anatomically and embryologically studied. Although they are not easily accessible to autopsy, study of the temporal bone is important for detection of congenital disorders. In this mummified fetus, measurements of the pars squama and pars basilaris of the occipital bones were in agreement with those of the long bones.

Autopsy of mummified corpses is technically difficult because the body lacks elasticity and breaks easily. MSCT is the only non-destructive tool available for mummy investigation, for example to assess bone abnormalities that remain hidden to direct visual examination because of the presence of dry flesh. This case report of a naturally mummified fetus illustrates the possibilities offered by MSCT for detection of skeletal abnormalities and also for estimation of gestational age using methods which cannot be directly applied at autopsy.

Acknowledgments

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