RadioGraphics

Scenes from the Past

Radiologic Evidence of Anthropogenic Mummification in the Capuchin Catacombs of Palermo, Sicily[1]

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The purpose of this study was to use paleoradiologic analyses to investigate a sample of the mummies in the Capuchin Catacombs in Palermo, Sicily, in order to assess skeletal abnormalities and the state of preservation, especially the condition of the internal organs, and to determine radiologic evidence of anthropogenic mummification. Ten 19th and early 20th century mummies with good external preservation were investigated by using a portable direct radiography unit inside the Capuchin Catacombs. The radiographs clearly demonstrated signs of anthropogenic mummification in nine of the 10 mummies investigated. The embalming methods that had been used included *(a)* evisceration and arterial injection; *(b)* the placement of foreign materials into the orbits and the nasal and oral cavities; and *(c)* filling of the thoracic, abdominal, and rectal cavities with foreign materials. Organ preservation varied greatly among the mummies, although brain tissue was found in all of the mummies. Analyses of the skeletal material of the mummies showed evidence of healed vertebral fractures, age-related degenerative changes, and, in one of the child mummies, a remarkable skeletal pathologic condition. The radiographs clearly illustrated different methods of anthropogenic mummification in the catacomb mummies of Palermo, allowed assessment of the preservation of the mummies, and demonstrated skeletal abnormalities.

Abbreviation: AP = anteroposterior

RadioGraphics 2010; 30:1123–1132 • **Published online** 10.1148/rg.304095174 • **Content Code:** OT

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Introduction

Mummification occurs when natural processes of decomposition are prevented. Processes of mummification are usually divided into two groups: spontaneous and anthropogenic. Bodies may mummify naturally in areas with extreme environmental conditions, such as aridity or cold. This process is known as *spontaneous mummification*. In other cases, intentional human activity assists in the preservation of bodies. Referred to as *anthropogenic mummification,* this approach is most commonly associated with the ancient Egyptians (1–3). The ancient Egyptian culture, however, was far from the only culture that mummified its dead. In many cases, a combination of anthropogenic and spontaneous mummification led to exceptional preservation of corpses. This is the case for the mummies of the Capuchin Catacombs in Palermo, Sicily.

The purpose of this article is to describe the results of a recent research project of the European Academy of Bolzano (EURAC). During the "SicMum" project, 10 mummies were examined inside the Capuchin Catacombs by using a portable direct radiography unit. The primary goal of the paleoradiologic analyses was to assess skeletal abnormalities (3–10). The radiographic studies also enabled *(a)* assessment of the state of preservation of the catacomb mummies, especially the condition of the internal organs, and *(b)* determination of anthropogenic mummification methods in the 19th and early 20th centuries in Sicily.

Who Is Buried in the Capuchin Catacombs in Palermo?

At the end of the 16th century, the Capuchin Catacombs of Palermo were constructed as a burial site for deceased friars. With time, huge subterranean corridors were carved out of the massive deposit of tuff that underlies the Capuchin Church and Convent area. The first bodies entombed in the crypt in 1599 were taken from an external common burial pit located near the church. By chance, many of these bodies were remarkably well preserved; this preservation was attributed to divine intervention. From the 17th century, aristocratic supporters of the Capuchin Order were also accorded the "privilege" of burial in the crypt. This practice was later extended to even the middle classes, who were also eager to have their bodies displayed as a symbol of social status. Today the catacombs form an impressive site where many mummies can still be seen (Figs 1, 2).

The results of a recent survey indicated that 1252 bodies are displayed along the corridors or in wall niches, and many of the bodies have retained some soft tissue. Although an additional 600 coffins are distributed throughout the crypt, some of these coffins are empty (1,2,11–13).

A total of 10 mummies, all of which showed a remarkable state of external preservation and were easily accessible for examination, were selected for radiography: six adult male mummies, one adolescent male mummy, and three child mummies, all of which were in burial containers, such as coffins. Several of the mummies could be identified from records; all of these mummies dated from the mid to late 19th and early 20th centuries. On the basis of the clothing style and the embalming procedure, the unidentifiable mummies were tentatively ascribed to the 19th century (D.P.M., unpublished data, September 2009). Except for two cases, all of the individuals were clothed, some extravagantly.

How Were the Bodies in the Capuchin Catacombs Mummified?

The preparation of the bodies for interment in the crypt was simple. To promote spontaneous desiccation, the corpses were laid on ceramic grids in small cells, to allow bodily fluids to drain away. The cells were then sealed for about a year, after which time the corpses were exposed to the air, washed with vinegar, and dressed (1,12). Some bodies were also preserved with other anthropogenic methods, such as dipping the body into lime after death during an epidemic (11,12) or arterial injection with special chemicals (2,12,14,15). Several conditions in the crypt also contributed to the long-term preservation of the bodies: low humidity, a cool but not frigid temperature, and good ventilation that derived from perpetually open windows.

The draining of bodily fluids was prohibited in Palermo in 1880 (12). Numerous coffins, some of which contained embalmed bodies, were stored in the catacombs until the mid 20th century (Provincial Archive of the Capuchin Friars, Palermo, Sicily; folders 5, 8, 43).

For the mummies examined in this study, some variation was seen in the method used to prepare the body after death. One individual seems to have been partially covered with lime, and at least three other mummies showed evidence of organ removal. One child, Rosalia Lombardo (Fig 3), was embalmed by Professor Alfredo Salafia, who was famous for his chemical embalming method at the time (14,15).

Figure 1. Photograph of the detail of one of the corridors of the catacombs shows its historical residents. Soon after death, bodies were left in special preparation rooms for about a year and then exposed to air, washed with vinegar, and clothed. If partial or no mummification had occurred, soft tissue was replaced with straw or tow, to impart a "right" consistency to the body. Standing in the middle is the anthropogenic mummy of Antonino Prestigiacomo (1844), still pristinely preserved. The embalming solution used to prepare this body may have contained arsenic and mercury, preservatives popular in the 19th century. (Courtesy of Gianluca Colla, Italy.)

Figure 2. Photograph of another view of one of the corridors of the catacombs. Bodies in the crypt had been sorted by age, sex, and profession. This original disposal of the dead was eventually prohibited in the late 19th century because of the stronger awareness of hygiene that followed the Italian unification (1861).

Figure 3. Photograph of Rosalia Lombardo (case 8), one of the three 20th century mummies in the Capuchin Catacombs of Palermo. This 2-year-old girl was embalmed by Alfredo Salafia in 1920 and transported to the Capuchin crypt for temporary entombment. Of interest is the remarkable appearance of the facial features, which probably is due to paraffin injection.

Radiologic Evidence of Anthropogenic Mummification and Organ Preservation in the 10 Examined Catacomb Mummies

Data	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7*	Case 8†	Case 9*	Case 10*
Sex	M	M	M	M	M	M	M	F	F	U‡
Age	Adult	Adult	Adult	Adult	Adult	Adult	Adoles	Child	Child	Child
Foreign bodies										
Eyes	–	–	+	+	–	+	–	–	–	+
Nose	+	+	–	+	+	+	–	–	+	–
Mouth	–	–	–	+	–	–	–	–	–	–
Filling										
Thorax	+	–	–	–	–	–	–	–	–	–
Abdomen	–	–	+	–	–	–	–	–	–	–
Rectum	–	–	+	–	–	–	+	–	–	–
Intraarterial	–	–	+	+	–	–	–	–	–	–
Organ preservation										
Brain tissue	+	+	+	+	+	+	+	+	+	+
Falx/tentorium	–	–	+	–	–	+	–	+	–	–
Lung	–	–	+	–	–	–	–	+	–	–
Heart	–	–	+	–	–	–	+	–	–	–
Diaphragm	–	–	+	–	–	–	+	–	–	–
Liver	–	–	–	+	–	–	+	+	–	+
Kidneys	–	–	–	+	–	–	+	+	–	–

Note.—Adoles = adolescent, + = finding depicted, – = finding not depicted.
*Inside coffin.
†Inside coffin with lead lining.
‡U = unknown.

Using Medical Imaging to Examine Catacomb Mummies

The term *paleoradiology* is used to describe the application of radiology to the analysis of ancient remains. Paleoradiology has been used as a nondestructive method of examining mummies since soon after the discovery of x-rays in 1895 (3–10). Radiography has the advantage of being affordable, accessible, and portable. With the development of high spatial resolution and full digitalization, the quality of soft-tissue discrimination was substantially enhanced (3,4,8,9), which enabled the improved analysis of ancient mummified tissue.

For the catacomb mummies, a mobile digital radiography system (Dragon DR, CXDI-50G; Canon Europe, Amstelveen, the Netherlands/Sedecal, Madrid, Spain) was constructed inside the catacombs in a corridor that was inaccessible to visitors. All three child mummies and the adolescent male mummy were examined while still within their coffins. The rest of the mummies were removed from the coffins for examination. The detector was placed directly under the body or the coffin for anteroposterior (AP) radiographs and was placed lateral to the body or coffin for lateral radiographs. All of the images were evaluated by the first author (S.P.), who is a senior radiologist with experience in paleoradiology.

Radiologic Evidence of Anthropogenic Mummification

Nine of the mummies demonstrated radiologically depicted signs of anthropogenic mummification (ie, foreign bodies or filling with foreign material). The radiographs of one mummy (case 8; Rosalia Lombardo) were of reduced quality because of the superimposition of the lead-lined coffin (Table).

Evidence of anthropogenic mummification was found throughout the bodies of the various

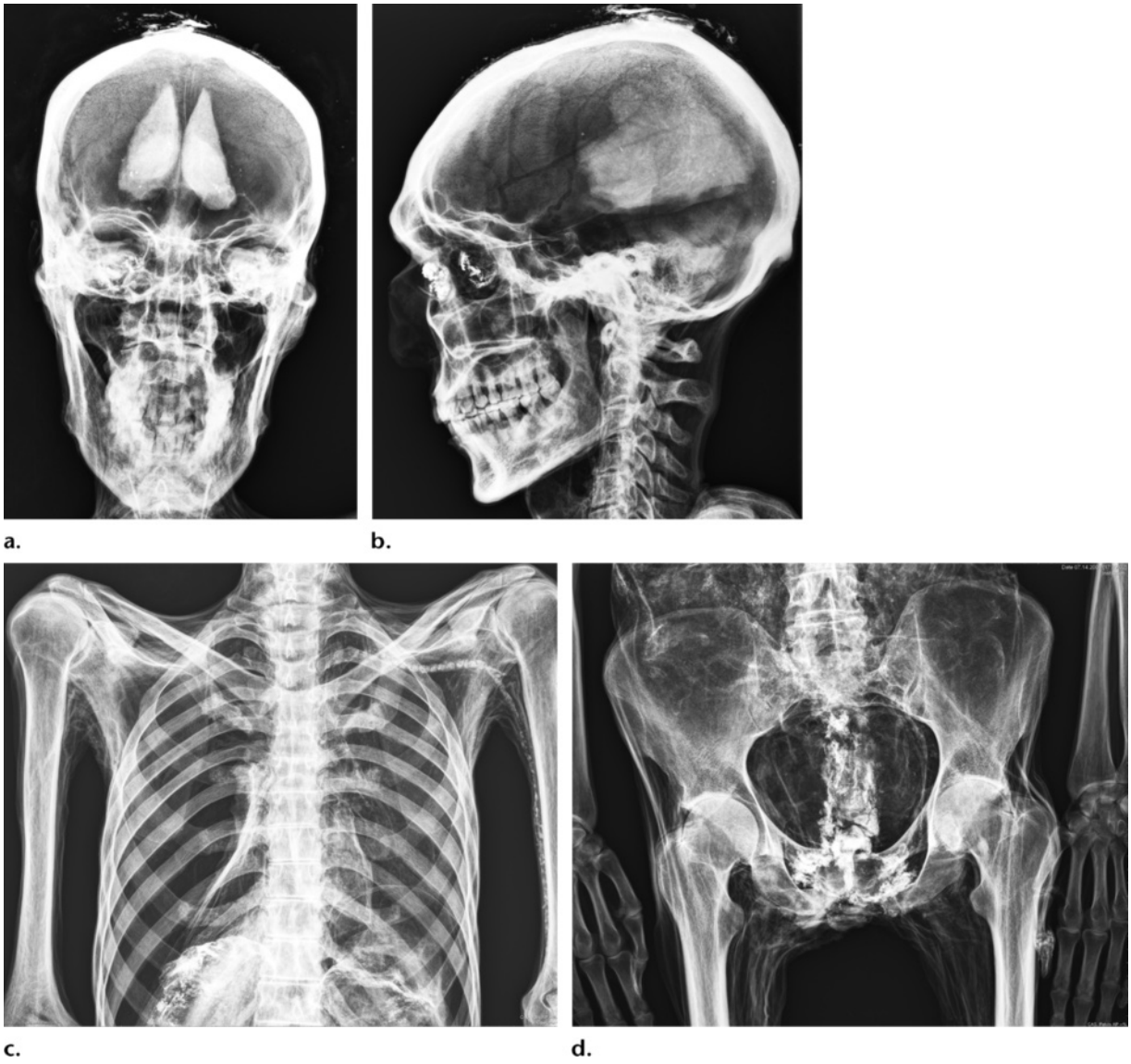
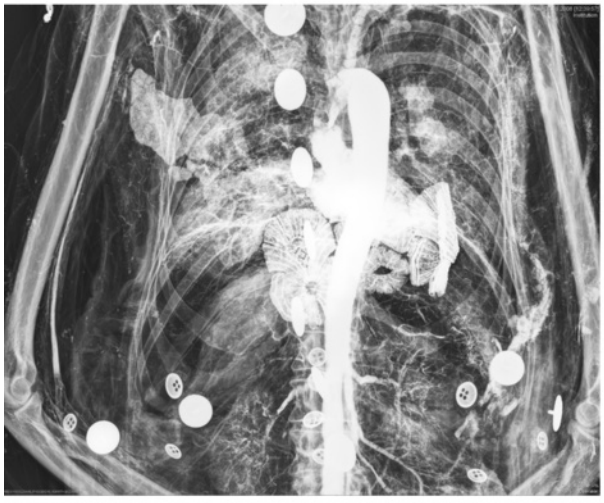


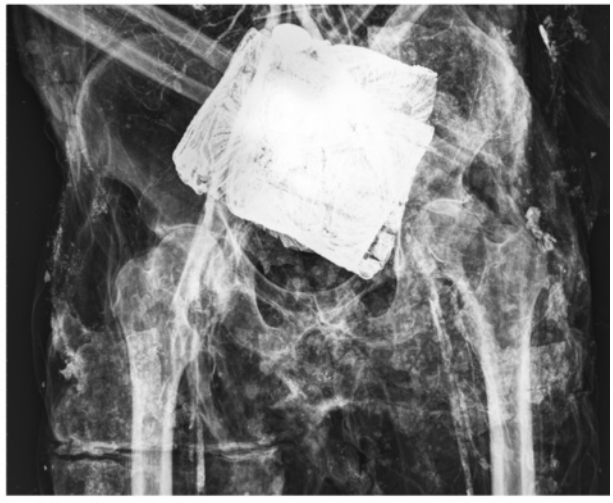
Figure 4. Adult male mummy (case 3). **(a, b)** AP **(a)** and lateral **(b)** radiographs of the head show radiopaque foreign bodies inside the orbits. Symmetrical, clearly shrunken, and radiopaque cerebral hemispheres are preserved next to the midline, with moderate dorsal dislocation. The falx is clearly depicted. Preserved cerebellar tissue is demonstrated as a radiopaque structure located centrally in the dorsal fossa. **(c)** AP radiograph of the chest shows crumbly radiopaque material in the left subclavian, axillary, and brachial arteries, extending to the distal humeral diaphysis. Foreign intraabdominal material can be seen in the region of the liver and spleen. The left hemidiaphragm, cardiac structures, and atelectatic lung on the right side are preserved. **(d)** AP radiograph of the pelvis shows filling of the rectum with radiopaque material, which is also distributed around the anal opening.

mummies. In several cases, radiopaque foreign material or metal plates or caps were found in the eye sockets (Figs 4a, 4b, 5a, 6a, 6b), and the nasal passages contained radiopaque textiles (Fig 5a). A radiopaque foreign material was found in the mouth of one mummy (Fig 5a). Radiopaque filling was found in the thorax, abdomen (Fig 4c), and rectum (Figs 4d, 7e). In one case, radiopaque material was clearly depicted in numerous arteries of the entire body, including both the thoracic aorta and the abdominal aorta (Fig 5).

a.



b.



c.

Figure 5. Adult male mummy (case 4). **(a)** Lateral radiograph of the skull clearly shows radiopaque foreign bodies in the orbits, the nasal passages, and the oral cavity. Preserved cerebral hemispheres are shrunken and radiopaque and are dislocated dorsally. The cerebellum is also preserved. **(b, c)** AP radiographs of the chest and abdomen **(b)** and the pelvis **(c)** demonstrate arterial angiographic findings after injection of a homogeneous and extremely radiopaque material that is shown inside the thoracic and abdominal aorta and the left ventricle and atrium. The left subclavian artery is filled to the axillary artery. On both sides, the vertebral arteries and the common, internal, and external carotid arteries are at least partially shown. On the right side, the brachial artery is filled to the elbow. Pulmonary veins are shown predominantly in the lower part of the right side of the chest. Both renal arteries are clearly depicted, and both kidneys show filling of the arterial vessels to the periphery, including interlobular arteries of the renal cortex. The superior and inferior mesenteric arteries, with parts of their branches, are clearly depicted. The aortic bifurcation, the iliac arteries, and the superficial and deep femoral arteries are filled on both sides. The upper part of the right leg is markedly thickened and shows a horizontal cut and diffuse radiopaque material, especially around the cut. The shrunken radiopaque liver is depicted in **b**. All three radiographs show superimposed ornaments of the clothes.

a.

b.

Figure 6. Child mummy (case 10). **(a)** Lateral radiograph of the head, chest, and abdomen shows metal caps beneath the eyelids inside the orbits. The mummy has marked kyphosis of the upper thoracic spine, a disproportionately large neurocranium, a midface hypoplasia with a depressed nasal bone, and irregular, somewhat crowded teeth. Note the preserved, dorsally dislocated, shrunken and radiopaque cerebral hemispheres. **(b)** AP radiograph of the chest, abdomen, and pelvis shows small stature and mesomelic limb shortening of upper extremities, as well as brachydactyly of both hands. Note the preservation of the shrunken radiopaque liver.

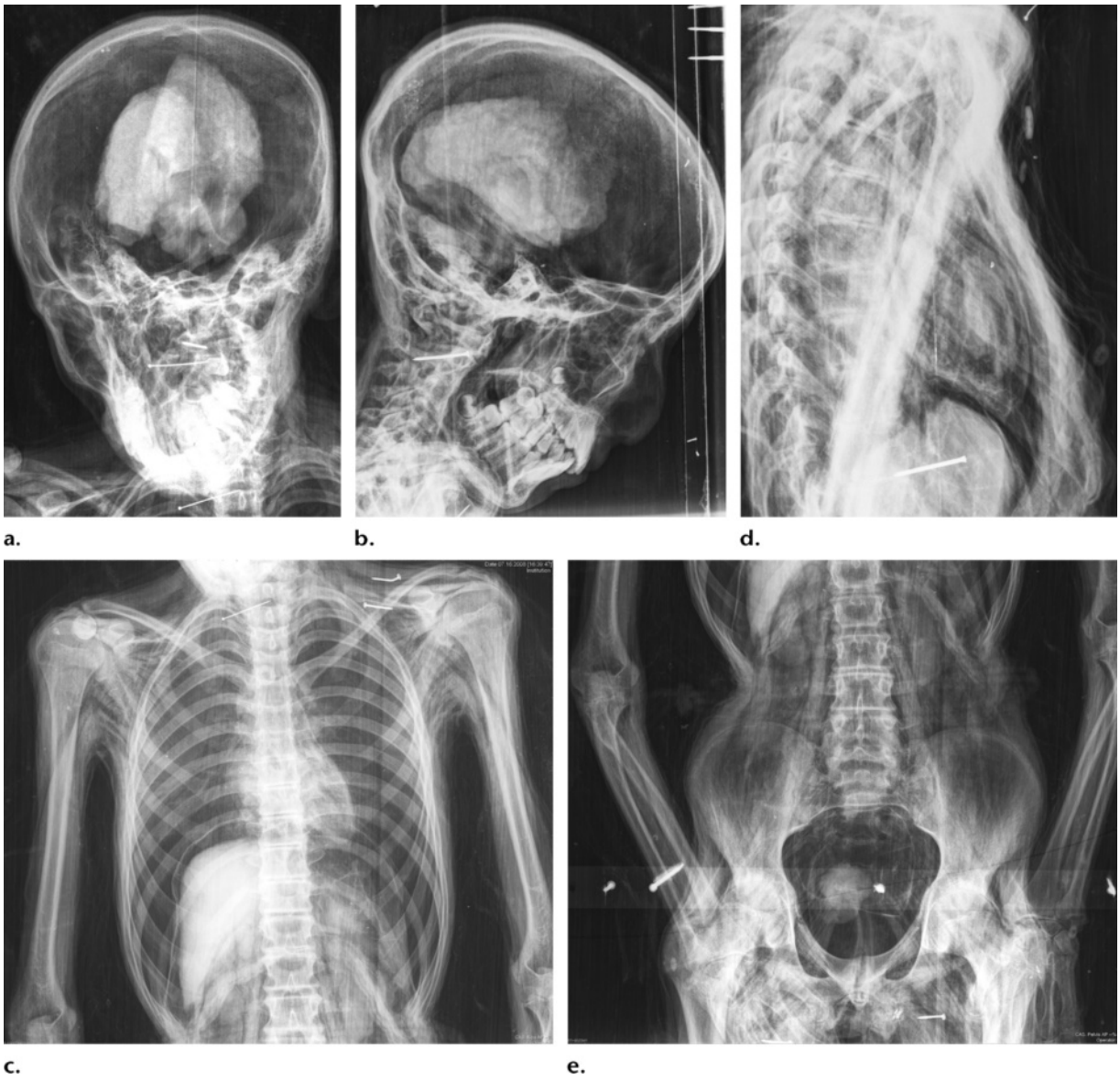


Figure 7. Adolescent male mummy (case 7). **(a, b)** AP **(a)** and lateral **(b)** radiographs of the head show shrunken and radiopaque cerebral hemispheres with convoluted surface. The frontal and temporal lobes are distinguishable. The hemispheres are dorsally dislocated. The cerebellum is also well preserved. **(c)** AP radiograph of the chest shows the preserved heart, the diaphragm bilaterally, the moderately shrunken radiopaque liver, and the slightly radiopaque kidneys. **(d)** Lateral radiograph of the chest shows detailed cardiac anatomic structures, with a slightly radiopaque ventricular cavity, transparent myocardium, and radiopaque epicardium and pericardium. **(e)** AP radiograph of the abdomen and pelvis shows preservation of the psoas muscle on both sides, as well as radiopaque intrarectal material.

Organ Preservation

Radiologically depicted organ preservation differed widely among the various individuals, as well as among the different organs (Table). Although preserved brain tissue was found in all 10 mummies, the quality and the extent of preservation were variable. In six of the mummies, both cerebral hemispheres were clearly depicted as conspicuously radiopaque, although they were clearly shrunken (Figs 4a, 4b, 5a, 6a, 7a, 7b, 8).

Abdominal and thoracic organs were also preserved in some of the mummies. In two cases, preserved cardiac structures were depicted (Figs 4c, 7c, 7d). The diaphragm was also preserved in the same two mummies. The liver was demonstrated in four mummies as a shrunken radiopaque organ (Figs 5b, 6b, 7c, 7d, 8). Slightly radiopaque kidneys were depicted bilaterally in two mummies

(Figs 5b, 7c, 7e) and on the left side in a third mummy (Fig 8). External genitalia were demonstrated on four male mummies. Parts of preserved shrunken musculature were depicted (Fig 7c, 7e), as were numerous tendons and the ligamentous structures of some of the mummies, including preserved cartilage in two of the child mummies.

Pathologic and Pseudopathologic Changes

Some of the mummies showed pseudopathologic changes, primarily postmortem skeletal dislocations. Healed compression fractures of three vertebrae were identified in one mummy; and the mummy of an elderly adult showed marked antemortem tooth loss and general degenerative changes to the skeleton, especially in the thoracic vertebrae.

One child mummy (case 10) manifested an interesting skeletal pathologic condition. The child was of unknown identity and sex. The bone age of both hands was equivalent to that of an approximately 3-year-old child, but the bone age of the spine, pelvis, both humeri, and both femora was clearly older. A marked kyphosis of the upper portion of the thoracic spine was demonstrated. The child also had reduced stature and shortening of the upper and lower limbs and digits. The skull of the child was dolichocephalic, with a slightly bulging forehead, depressed midfacial skeleton, and somewhat crowded teeth.

Discussion

Radiologic signs of anthropogenic mummification were depicted in nine of the 10 mummies investigated in this research study. The insertion of foreign objects and materials is common in these mummies, such as the metal caps in the orbits, the radiopaque textiles in the nasal passages, and the various embalming materials. Some of the radiopaque embalming material was introduced abdominally, and other material was inserted in the form of an enema. Radiopaque intraarterial material was clearly demonstrated in two cases. Historical accounts report that the first embalmer who relied exclusively on intraarterial injection was the Sicilian Giuseppe Tranchina (1797–1837), anatomist at the Royal University of Palermo. Tranchina's approach consisted of an alcoholic or aqueous solution of arsenic and cinnabar (red mercuric sulfide) (16). Arsenic and mercury were substances widely adopted by Sicilian embalmers (2), and these substances remained the most popular embalming chemicals for much of the 19th century (17).

Figure 8. Two-year-old female mummy of Rosalia Lombardo (case 8). AP radiograph of the head, chest, and abdomen shows the moderately shrunken, symmetrical radiopaque cerebral hemispheres; parts of the right lung; the slightly shrunken radiopaque liver; and the left kidney. Image quality is reduced because of the superimposition of the lead-lined coffin.

By 1901, another Sicilian, Alfredo Salafia (1869–1933), developed a new method resulting in successful long-term embalming. Salafia, a taxidermist and embalmer from Palermo, began by preserving animal bodies and went on to preserve cadavers for dissection and funeral preparation. In 1910, Salafia became established in New York City and popularized his embalming method. The method consisted of the injection of 7 L of embalming fluid into the vascular system, without draining blood, eviscerating the body, or injecting any additional substances. The body of Rosalia Lombardo, which is included in this study, was preserved by Salafia in 1920 (15).

The embalming material was detectable in radiographs as a result of the chemical composition of the embalming materials. Compounds containing arsenic (18) are not sufficiently radiopaque to be depicted with radiography. The addition of mercury, however, provides a high degree of radiopacity. Cases 3 and 4, in which the subjects were probably embalmed during the mid to late 19th century, demonstrate some

radiopaque intraarterial material. In addition to the arsenic solution, the embalming fluid must have contained mercury in both cases. It was also possible to determine the method used for the distribution of the embalming fluid in two cases, on the basis of the presence of the material in different parts of the body.

Radiographically depicted preservation of the internal organs of the catacomb mummies differed to a great extent. All organs depicted in the radiographs of the mummies were reduced in size and demonstrated an increased radiopacity in comparison with the organs in radiographs of living human beings. Hübener and Pahl (19), in their discussion of computed tomographic studies of Egyptian mummies, explained that shrunken organs in mummies become more radiopaque, primarily because of the collapse and desiccation of the tissue. Different embalming materials might also change the absorption of various substances (4,19).

The preservation of the brain in all of the mummies that were examined was surprising. In agreement with the findings of previous studies (12,20–22), the preserved brains represented not more than about 20% of their original size, except the brain of Rosalia Lombardo, which was reduced to only approximately half of its original size. The brain, which is normally considered an especially perishable organ, can prove resistant to destruction in the state of adipocere formation. Adipocere formation is extremely rare in dry environments, such as the catacombs of Palermo; there is no evidence for adipocere in any of the mummies. Therefore, it can be assumed that the good overall preservation of the brain in the catacomb mummies is mainly due to chemical processes caused by the use of the different embalming fluids.

The results of this research did not allow a clear correlation between radiologic signs of anthropogenic mummification and the state of organ preservation in all cases. The mummy that was allegedly covered with lime did not reveal any organ preservation except for poor remnants of the brain; the surface application of lime seems to have restricted preservation to mainly the surface structures of the body. The two bodies that had been injected with arsenic and mercury solutions showed good preservation of the brain, as well as preservation of the thoracic organs in one case and preservation of abdominal organs in the other. The body of Rosalia Lombardo was known to have been embalmed with a formaldehyde-based solution and showed remarkable organ preservation.

An assessment of pathologic conditions in the mummies showed no indicators of metabolic disease or changes that resulted from nutritional disorders, possibly because of the high social status of the deceased. Healed vertebral fractures were found in a single individual, and the expected generalized degenerative skeletal changes were found in an elderly adult.

The skeletal syndrome found in one child mummy is remarkable. The diagnosis of genetic syndromes in paleopathologic cases is often difficult because of the lack of clinical information and the unavailability of specific phenotypic soft-tissue features, especially those of the face. The physical features identified in the radiologic analysis of this child mummy led to the suggestion that the child had Robinow syndrome. Robinow syndrome, or the so-called fetal face syndrome, was first reported by Robinow and coworkers (23) in 1969 as a dwarfism syndrome consisting of mesomelic limb shortening, short fingers, hypoplastic genitalia, and characteristic facies resembling that of a fetus at 8 weeks. Robinow syndrome is a genetically heterogeneous condition that can be inherited in an autosomal dominant or recessive mode, in which the recessive form tends to be more severe. This syndrome is extremely rare, with slightly more than 100 modern cases reported worldwide (24–26). Whether the kyphosis in this case is the result of the positioning of the mummy in the coffin or is one of the characteristic findings of Robinow syndrome remains unclear. The typical hypoplastic genitals found in male and female subjects with Robinow syndrome, as well as further soft-tissue facial characteristics, could not be assessed. The differential diagnosis for the pathologic condition of this child includes Aarskog syndrome, acrodysostosis, and pseudohypoparathyroidism with severe facial and acral involvement (24). Despite his or her obviously striking features, this child received a privileged burial within the catacombs.

Limitations of the Study

The superimposition of coffin materials and the presence of clothing with partially radiopaque buttons, cuffs, and ornaments sometimes made interpretation of the radiographic images difficult. It was not always possible to obtain radiographs in the specific desired projection for various reasons, such as the stiffness of the mummies and the inability to remove some mummies from their coffin for additional external visual examination.

No reference methods were available for this study because complete physical examination of the clothed bodies was only possible in few cases, and targeted biopsies were not possible at all.

Conclusions

The findings from the radiologic analysis described in this article represent the first scientific investigation of the mummies from the Capuchin Catacombs of Palermo. The results of this investigation are an important contribution to the field of paleoradiology and illustrate special methods of anthropogenic mummification of the catacomb mummies from Palermo, in agreement with the historical evolution and development of embalming, especially concerning the embalming chemicals. Radiologic examination remains an extremely valuable tool to assess the preservation status of internal structures, supplementing the examination of external preservation of the mummy and allowing the evaluation of skeletal abnormalities.

Acknowledgments.—We are indebted to the Order of the Capuchin Friars of Palermo for granting permission to investigate this sample of mummies. We are also grateful to Sedecal (Madrid, Spain) and to Canon Europe (Amstelveen, the Netherlands) for their valuable logistic and technical support. Special thanks are due to Heather Gill-Robinson, PhD, who commented on the original manuscript, and Gianluca Colla, professional photographer, for loaning us Figure 1.

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