

Radiography of Ancient Egyptian Mummies

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FIGURE 1—Pelvic region of a naturally desiccated body of predynastic times (before 3400 B.C.). There is well-marked osteoarthritis of the lumbar vertebrae but no evidence of opacification of the intervertebral disks.

ALTHOUGH mummies have been studied very thoroughly from many aspects, the use of radiography has, for some unaccountable reason, been neglected to a large extent. The gross anatomy of mummies has been well covered by Smith and Wood-Jones¹ and the histologic aspects by Ruffer² in 1921 and by Sandison³ in 1963. However, these studies were necessarily destructive, entailing the unwrapping and dissection of the specimen.

Almost immediately after Röntgen discovered x-rays, the value of radiography was recognized by Petrie,⁴ who published excellent radiographs of the legs and the feet of some of his mummies. One of these (Plate XXXVII) showed well-defined lines of arrested growth in the lower end of a tibia. It is extraordinary, however, that Petrie made no mention of this radiograph in his text. In 1931, Moodie⁵ briefly described his radiographic findings in 17 ancient Egyptian mummies.

A life-size radiograph of an Egyptian mummy was reproduced in an early issue of *Radiography and Clinical Photography*,⁶ the predecessor of this journal. The mummy, lying supine in an open wooden coffin, was radiographed in the Field Museum of Natural History, Chicago, on a sheet of x-ray film measuring 24 by 84 inches. Judging by the position of the arms and the general treatment of the body, the mummy probably dates from the late Dynastic or Early Ptolemaic period (664 to 332 B.C.). The text accompanying the illustration states: "X-ray investigation eliminates laborious unwrapping of the body in general study of mummies or in search of jewelry and precious metals."

Since radiography has no deleterious effect on a wrapped mummy, and in view of the paucity of reports on the radiologic examination of mummies, it was thought worthwhile to obtain permission to radiograph the specimens in the museums of Great Britain and other European countries. The objectives were to determine the presence or the absence of human bones; to determine the age and the sex of the person; to correlate the radiographic findings with the various embalming techniques; to demonstrate amulets within the wrappings; and to demonstrate pathologic changes.

MUMMIFICATION

Mummies hold a fascination for many people, even those who have little or no interest in history. To most, the term "mummy" automatically means Egyptian mummy, although other cultures practiced mummification. The custom was prevalent in Egypt for over 30 centuries, but the procedures used underwent considerable change in that period.

In the earliest times, the Egyptians buried their dead, usually naked, in shallow graves in the sand, with the limbs flexed and the body contracted (Figure 1). The hot, dry sand desiccated the body and protected it from the atmosphere, so that decomposition was arrested. No doubt, from time to time, some of these naturally pre-

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served bodies were exposed by grave robbers or by shifting sands, and their appearance may have originated or, at least, stimulated belief in life after death. This belief led to the provision of food and equipment for the use of the dead in their continued postmortem existence, necessitating larger graves, or tombs, constructed of wood or stone. However, the roomier tomb allowed the body to come into contact with the air, and decomposition resulted. The contrast in appearance between a well-preserved, naturally desiccated body and a decomposed corpse in a large, well-equipped tomb probably suggested the idea of mummification, that is, to preserve the body artificially from decomposition and obtain by human means that which unaided nature had achieved in the simple graves in the sand.

It is almost certain that the earliest attempts at mummification were made for royalty. However, as time passed, the practice became more democratic, and commencing with the nobility, was eventually extended to all who could afford the cost. Herodotus,⁷ who visited Egypt in the fifth century before Christ, wrote that, at the time, three methods of mummification were employed. The first was the "most costly way," the second was less costly, and the third was reserved for the "poorer classes." It is likely that the expensive method would cost several hundred pounds by present standards.

As early as the Fourth Dynasty (2613 to 2494 B.C.), the corruptible viscera were removed through an incision in the left flank and were placed in so-called Canopic

*Natron is a mixture of sodium carbonate, sodium bicarbonate, and many impurities, such as the salts of iron, calcium, and silicon.

jars. The body was then treated with natron,* desiccated, anointed, and bandaged. However, most mummies embalmed before the Eighteenth Dynasty (1567 to 1320 B.C.) appear to have been imperfectly desiccated and fall to dust when unwrapped, leaving little but bones. The method described by Herodotus for removing the brain (by extraction through the nostrils) was probably not used before the Eighteenth Dynasty.

Considerable progress was made in mummification from the Eighteenth to the Twentieth Dynasty (1567 to 1085 B.C.), and much accurate information has been derived from close study of the royal mummies found in 1881 in the Theban necropolis.

The art of mummification reached its peak during the Twenty-first Dynasty (1085 to 935 B.C.), and we owe much of our knowledge of the methods used at that time to Sir Grafton Elliot Smith,⁸ who described the procedure in 1906. The embalmers of the period followed the ancient practice of evisceration through an incision in the left flank and extraction of the brain through the nostrils. However, the general treatment of the body differed widely after these two preliminary procedures. The extracted viscera were no longer placed in Canopic jars but were wrapped in four parcels and restored with packing material, such as sawdust, to the body cavity (Figure 2). Each parcel contained the appropriate wax or clay figurine of one of the four sons of Horus, the falcon god, who were guardian deities of the stomach, lungs, liver, and intestines. The heart, considered the seat of the emotions, was always left in situ. If accidentally severed from its connections during evisceration, it was always

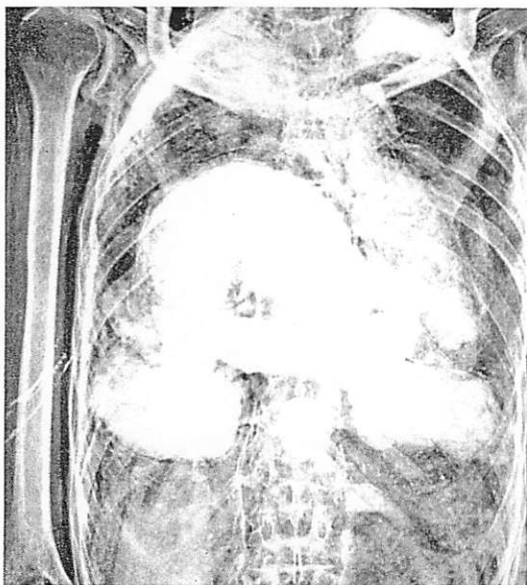
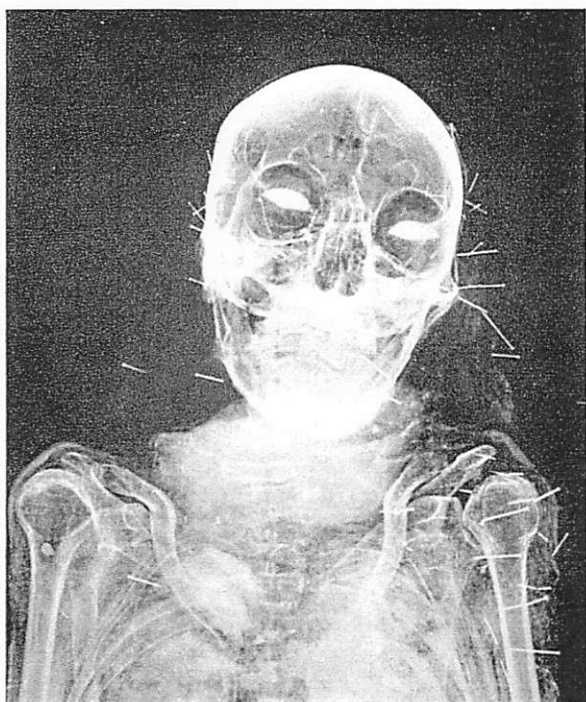


FIGURE 2—Thorax and upper part of the abdomen of mummies of the Twenty-first Dynasty (1085 to 935 B.C.) showing visceral packs within the body cavity. In this era, the stomach, lungs, liver, and intestines, after removal, were packaged in separate parcels and restored to the body cavity. Left: Note the large pectoral amulet. Below it is a heart scarab. Both of these objects are within the bandages. Right: The opacification of the intervertebral disks between the thoracic vertebrae is almost certainly the result of the embalming process, not alkaptouria.



replaced, even stitched back, in its correct anatomic position. A wax or metal plate bearing the "symbolic eye" was placed over the wound in the flank. To make the body appear more lifelike, mud was packed under the skin to restore the contours and artificial eyes were placed over the shrunken orbits (Figure 3, upper left, and Figure 4). The digits received special treatment to prevent loss of the nails, a custom started at least as far back as the Twelfth Dynasty.

The embalmed body, painted with ochre (red for men and yellow for women), was then ready for the lengthy and elaborate process of bandaging. After bandaging, it was placed in the cartonnage mummy case, which consisted of many layers of linen cemented together and sometimes covered with a layer of stucco. The cartonnage was subsequently placed in an inner coffin, which, in turn, was placed in an outer coffin. In the final ceremony before being committed to the tomb—the "Opening of the Mouth"—the officiating priests, by a series of magical spells and gestures, restored life to the dead senses and the power of motion to the lifeless limbs. The entire process of mummification, from time of death to final enclosure in the tomb, usually took 70 days.

This procedure was maintained during the Twenty-second and Twenty-third Dynasties (935 to 730 B.C.) and was used occasionally but less carefully until the Twenty-sixth Dynasty (664 to 525 B.C.). In the Twenty-sixth Dynasty, the use of artificial eyes and subcutaneous packing was largely abandoned. The viscera were no longer restored to the body but were packaged and placed between the legs (Figure 5) or were deposited in Canopic jars, the use of which had been revived.

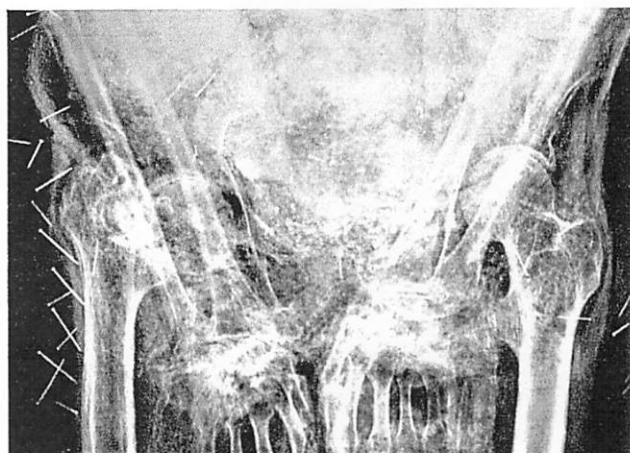


FIGURE 3—Radiographs of a mummy in the Rijksmuseum, Leiden. The pins used to hold the bandages in place are modern. Upper Left: Note the artificial eyes and the mud packed under the skin around the neck to render the contours of the corpse more lifelike. This treatment of the body was mainly confined to the Twenty-first and Twenty-second Dynasties (1085 to 730 B.C.). Upper Right and Lower Right: Antemortem intertrochanteric fracture of the right hip, with formation of a false joint, and marked calcification of the arteries in the thighs.

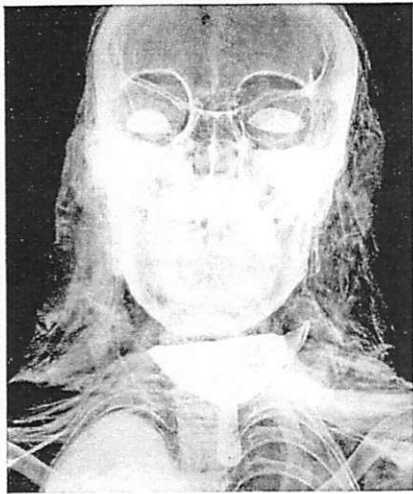


FIGURE 4—Mummy of a woman of the Twenty-first Dynasty showing artificial eyes and a mass in the right side of the thorax. There is an amulet about the neck within the bandages.

In the Ptolemaic period (332 to 30 B.C.), the use of natron was largely abandoned in favour of molten resin, which was poured into the body cavity via the embalming wound and into the skull via the nostrils (Figure 6, left, page 38). With time, less and less care was taken with the treatment of the body (Figures 7 to 9, pages 38 and 39), and more and more attention was given to the binding and appearance of the wrapped mummy (Figure 10, page 40). During the Roman period, the bandages were often applied in an elaborate geometric pattern, and a painted portrait panel of the deceased was often incorporated in the bandages covering the head.

The practice of mummification declined about the third century of the present era, but it was carried on in a crude form by the Christian Copts until the Arabs invaded Egypt in A.D. 640.

RADIOGRAPHIC FINDINGS

Radiographic findings fall into two major categories of interest—archaeology and palaeopathology. The archaeologist is interested in determining when various cultures flourished and how these cultures changed with the passage of time. In order to achieve an accurate chronologic dating system, he must piece together bits of information from many sources—accuracy is of fundamental importance. The palaeopathologist is interested in the diseases that afflicted the ancients in order to determine the history of man's diseases.

Archaeology

DETERMINATION OF PRESENCE OR ABSENCE OF HUMAN BONES—The large museums of Great Britain and other European countries contain many mummies purchased in Egypt by early nineteenth-century explorers and travellers. The native dealers were quick to realise that a good profit



FIGURE 5—Radiograph of a mummy of the Twenty-sixth Dynasty (664 to 525 B.C.). The dense object between the legs is probably a visceral pack. At this time, the viscera were no longer returned to the body cavity but either were wrapped and placed between the legs or were put in Canopic jars, the use of which was then being revived.

could be made from the sale of "souvenirs" and mummies—and forgeries were by no means uncommon. In 1837, Scott⁹ wrote: "for the eagerness with which every sort of trash is purchased by travellers makes the trade a very profitable concern, and opens a wide door for fraud, by the encouragement it gives to the manufacture of mummies."

This study has confirmed Scott's statement. On many an occasion, a traveller had been sold not a mummy but a modern fake. Sometimes, a coffin proved to be empty or perhaps contained only a few bones. In one case, the wrappings of what was purported to be a mummy with a painted vellum mask concealed a concoction of wire and wood (Figure 11, page 40). In some instances, there was nothing inside the wrappings; in others, there was a centre core of wood or clay about which the bandages had been wrapped. Some small mummies, ostensibly those of children, were, in fact, the bandaged remains of birds.

DETERMINATION OF AGE AND SEX—A coffin can usually be dated by its orthography and style, but it cannot be assumed that the coffin contains its original inhabitant. For example, a coffin bearing the names and the titles of a man may contain the mummy of a woman, and vice versa. Furthermore, the period to which the coffin belongs may differ widely from that of its occupant. In one case, a specimen appeared to be the unwrapped mummy of a woman 75 years old. Radiography, however, showed it to be that of a girl about 17 years old.

FIGURE 6—Radiographs of a mummy in the Rijksmuseum, Leiden, showing a profusion of amulets. The lateral radiograph of the skull shows a mass of solidified resin in the posterior portion of the cranial vault. After the brain had been removed, molten resin was poured through the nostrils. The dense object lying on the surface of the lips was removed under fluoroscopy and proved to be a small disk of solid gold. The object behind the neck is a so-called miniature headrest. Note the bracelets on the wrists in the radiograph at the far right. The ovoid object in the region of the left iliac fossa is probably an amulet covering an incision in the left flank through which the viscera had been removed.

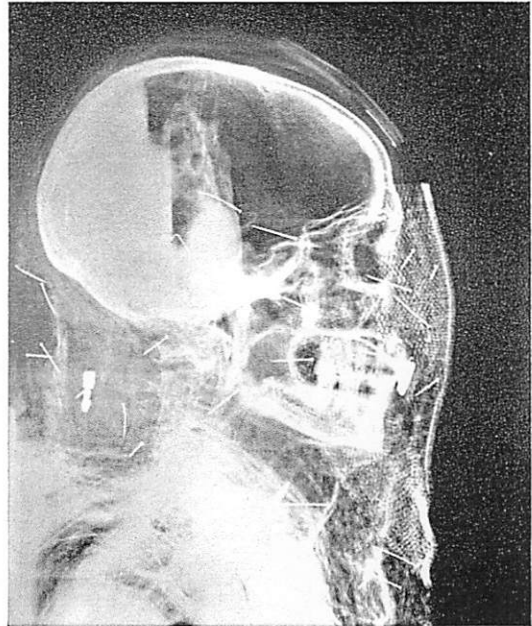


FIGURE 7—Late-period mummy of a child. The body cavity is filled with rubbish, that is, a mixture of potsherds, stones, and sand. Less and less care was taken in the treatment of the body during the late periods.



FIGURE 8—Radiograph showing careless treatment of the body of a mummy of the late Ptolemaic or the early Roman period. The artificial eyes and eyebrows are set into the cartonnage mask covering the head.

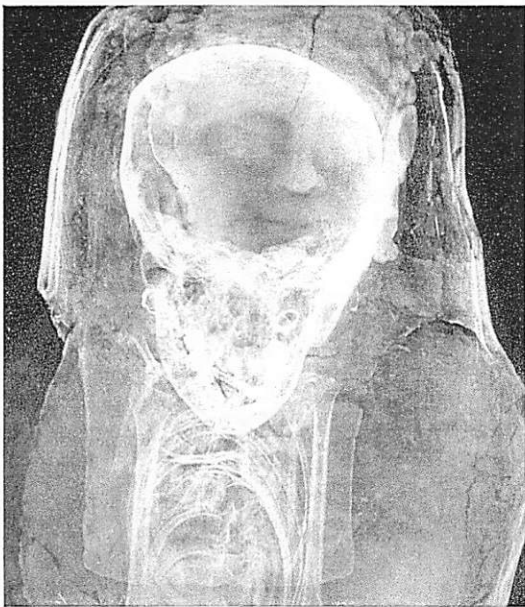
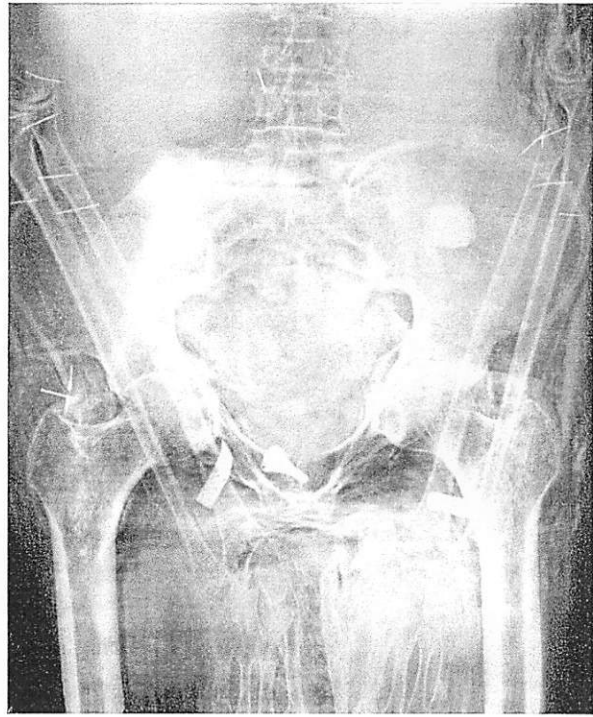
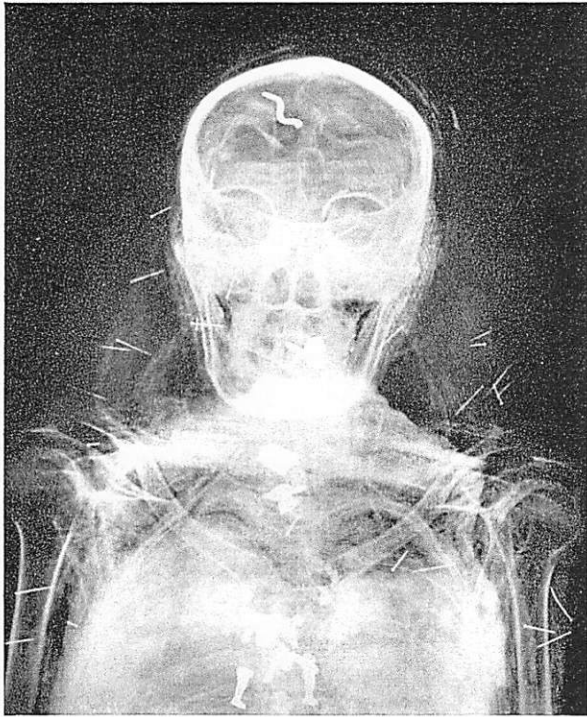


FIGURE 9—Mummies of children of the Roman period. Left: Skeletal compression resulting from very tight bandaging when the body was in an advanced state of decomposition. Note the earrings left in situ and the face mask. Right: Realistic modelling of the plaster face mask.

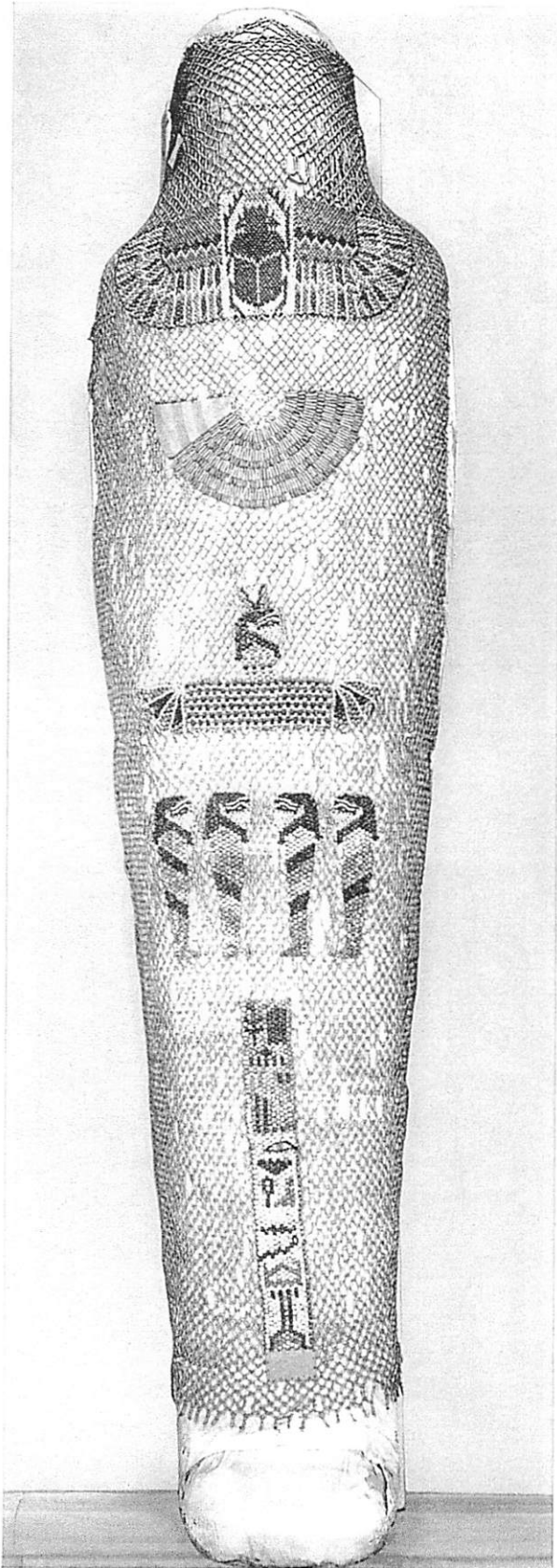


FIGURE 10

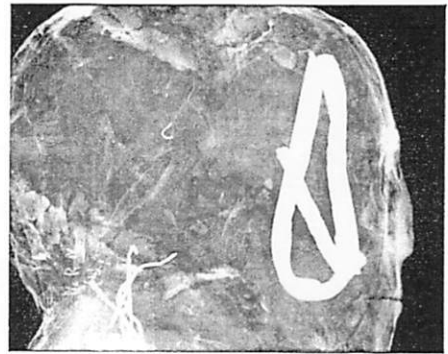
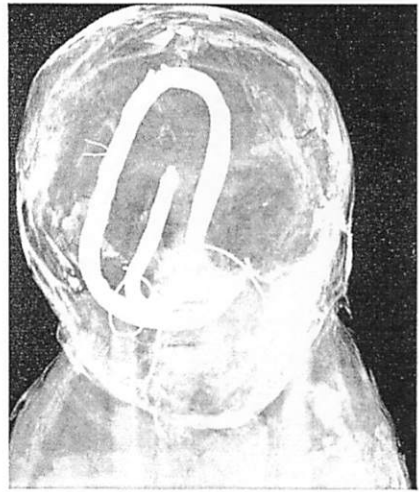


FIGURE 11

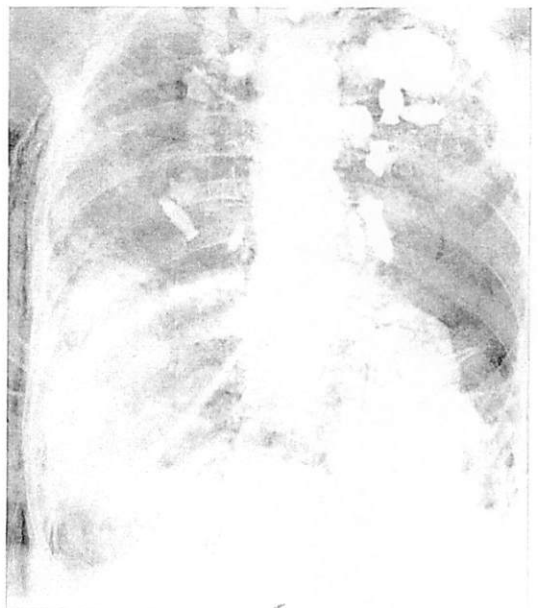


FIGURE 12

FIGURE 10—Photograph of a mummy, probably of the Twenty-sixth Dynasty or the early Ptolemaic period, covered with an elaborate bead net. There is a winged scarab around the neck. Below the scarab is a decoration of Hathor, the goddess of love. The four children of Horus are depicted. Here, there is evidence of carelessness, since all of the "children" are human headed. Below this, also in beadwork, is a vertical band of hieroglyphs wishing the deceased a successful burial. Radiographs revealed the mummy to be that of an elderly man who had dental disease, calcification of the arteries in the legs, and an antemortem transcervical fracture of the left hip.

FIGURE 11—Anteroposterior (upper) and lateral (lower) radiographs of the "head" of a fake mummy. The head is covered with a painted vellum mask, the "features" of which are faintly discernible in the lateral view.

FIGURE 12—Mummy of the Ptolemaic period showing a profusion of amulets within the bandages.

CORRELATION OF RADIOGRAPHIC FINDINGS WITH KNOWN EMBALMING TECHNIQS—It has been possible to correlate radiographic findings with known embalming technics, especially in mummies of the Twenty-first Dynasty wherein the salient features are visceral packs within the body cavity, artificial eyes, and subcutaneous plumping of the body (Figure 2, page 35, and Figure 3, upper left, page 36). Visceral packs between the legs (Figure 5, page 37) suggest embalment during the later dynasties. Masses of solidified resin within the body cavity and the skull (Figure 6, left, page 38) are characteristic of mummies of the Ptolemaic period.

However, many more specimens should be radiographed and unequivocal corroborative archaeological data must be available before any definite conclusions can be made.

DEMONSTRATION OF AMULETS—For religious reasons, amulets, made either of faience (pottery) or metal, were frequently incorporated in the wrappings (Figures 2, 6, and 12). Being radiopaque, the amulets can be detected easily, and when desirable, can be and have been localised with ease and removed through small incisions in the wrappings (Figure 6).

Palaeopathology

To date in this study, a radiographic survey of 133 ancient Egyptian mummies has been made. It seems likely, provided more specimens are examined and accurate archaeological data are available, that a chronologic dating system will be achieved. However, the survey was not undertaken solely with this aim in view; considerable emphasis has been placed on the search for palaeopathologic features. Radiology of wrapped mummies has its limitations owing to the dense materials sometimes used by the embalmers. However, it was felt that any advance in our knowledge of palaeopathology would fully compensate for the disadvantages in such an undertaking. As



FIGURE 13—Radiograph showing lines of arrested growth at the distal ends of the tibiae. Note the bead-net covering of the mummy.

Moodie⁵ pointed out, "Roentgenology supplements all other methods of learning of physical troubles in early times."

It was originally thought that only bony lesions would be found. Such, however, was not the case, as pathologic conditions of other systems were found. Space prevents a full description of each mummy, so only a brief list of the conditions encountered to date can be included.

OSTEOARTHRITIS—Osteoarthritis of the vertebral column was common (Figure 1, page 34). Of the 133 mummies examined, 88 were those of adults. The incidence of changes in the vertebral columns of these 88 is as follows:

Sex	Number	Osteoarthritic Changes Present	
		Number	Approximate Percent
Male	39	9	23
Female	27	2	7
Unknown	22	6	27

Osteoarthritic changes of the joints proved less common and were mainly confined to the hips.

LINES OF ARRESTED GROWTH—These were present in a little over 30 percent of the 133 mummies examined. The lines, found most often in the lower ends of the tibiae (Figure 13), suggest a general poor state of health during adolescence in ancient Egypt.

FRACTURES—Numerous fractures and dislocations were found, especially in late-period mummies, but they were nearly all postmortem. Occasionally, antemortem fractures were found. Figure 3, upper right (page 36), shows an antemortem fracture of the right hip with formation of a false joint.

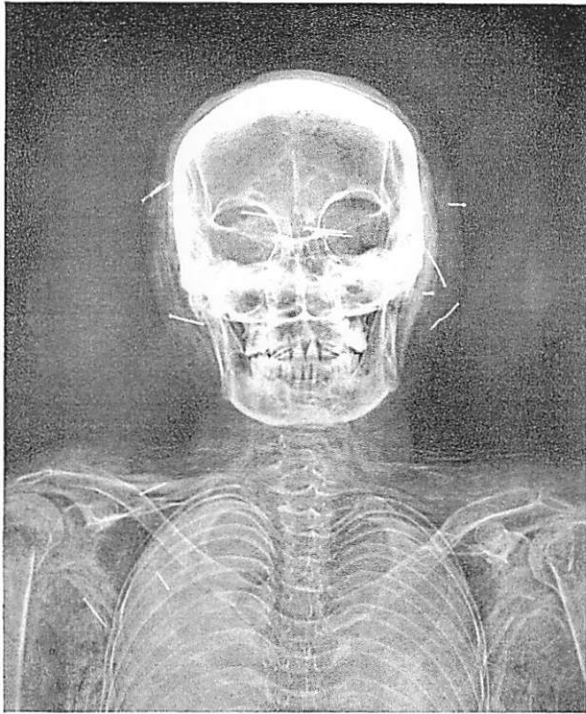


FIGURE 14

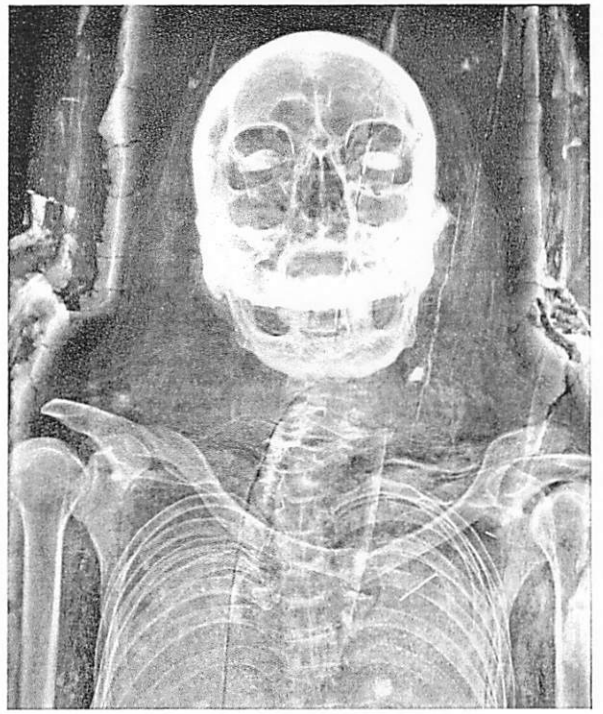


FIGURE 15



FIGURE 16



FIGURE 17



FIGURE 18

FIGURE 14—Radiograph of a mummy of the Roman period. Note the dental cyst in the angle of the right side of the mandible. The fractures of the humeri are most likely postmortem.

FIGURE 15—Radiograph of a mummy showing an edentulous jaw and artificial eyes.

FIGURE 16—Mummy of a woman showing a cluster of what is almost certainly gallstones.

FIGURE 17—Lateral radiograph of the vertebral column of a child of the Roman period showing marked opacification of the disks between the lower lumbar vertebrae. The opacification is almost certainly the result of the embalming process.

FIGURE 18—The apparent opacification of the intervertebral disks of this mummy of the Roman period is undoubtedly the result of the embalming process.

An interesting feature (not illustrated) was observed in a mummy of an elderly man from the Ptolemaic period. At some time during his youth, his left forearm had been severed a few inches above the wrist. Radiography showed that an artificial limb, complete with digits, had been fitted onto the withered limb when he was embalmed many years later.¹⁰

OTHER BONY FEATURES—The state of the feet indicates that restrictive footwear was not worn. Several examples of congenital abnormalities (spina bifida being the most frequent) were encountered. Other lesions found include infarction, enchondroma, and osteogenesis imperfecta (tarda), which are not illustrated, and cyst (Figure 14).

DENTAL CONDITIONS—Dental disease and attrition were found to be very common (Figure 15). A large dental cyst (Figure 14) was observed in the mummy of a woman in the Rijksmuseum, Leiden.

LESIONS OF SOFT TISSUES—Among the 27 mummies in the museum in Leiden, 20 are those of adults. In at least four of these, there was extensive calcification of the arteries of the legs (Figure 3, upper right and lower right). Had the survey been confined to the Leiden collection, it would have appeared that arteriosclerosis was prevalent. However, only one case of arteriosclerosis was found elsewhere.

Gallstones were almost certainly present in one of the 133 mummies (Figure 16) and were possibly present in another. A ureteric calculus was almost certainly present in another (not illustrated).

In many of the mummies, the intervertebral disks were opacified (Figure 2, page 35, and Figures 17 and 18). This opacification is almost certainly the result of the embalming process, and not of disease.¹¹

IMPORTANT DISEASES NOT FOUND—No evidence of the following important diseases was found in the skeletons of the mummies: malignant neoplasia, tuberculosis, syphilis, leprosy, rickets.

RADIOGRAPHIC TECHNIC

The ideal place to carry out a radiographic examination of a mummy is, of course, a well-equipped department of radiology. A preliminary fluoroscopic examination of the specimen should be made to ascertain the presence of bones and to determine the integrity of the skeleton, the position of the bones, and the state of embalment.

It is not always possible to carry out an examination under ideal conditions, however, because museum authorities may be reluctant to have a mummy removed from the premises, making it necessary to resort to less sophisticated facilities. All of the radiographs in this survey were made using small portable x-ray units.

Preliminary scout radiographs are sometimes necessary to serve as guides to correct exposure factors and to locate items or areas of specific interest.

X-ray Films and Intensifying Screens

KODAK BLUE BRAND X-ray Film* and medium-speed intensifying screens were used throughout the survey to make radiographs of the mummies. KODAK KODIREX X-ray Film† was used for radiography of small specimens and the extremities of thick subjects.

Because of the desiccation of the mummies, it was generally not necessary to use a grid.

Exposure Factors

The exposure factors found in most instances to be satisfactory for radiography of a mummy in a cartonnage are presented in Table 1; those for a mummy not in a cartonnage are presented in Table 2.

Processing

One difficulty in making a survey of this type away from a fully equipped x-ray department is the lack of immediate access to processing facilities. Few museums have such facilities, and the nearest darkroom may be some distance from the museum.

All of our exposed film was developed in KODAK DX 80 Developer‡ and fixed in KODAK UNIFIX Fixer.‡

*Product of Kodak Limited, London, England, which is analogous to KODAK BLUE BRAND Medical X-ray Film (Editor).

†Product of Kodak Limited, which is analogous to KODAK No-Screen Medical X-ray Film (Editor).

‡Product of Kodak Limited.

Table 1—Mummy in Cartonnage

Part	Kv	Ma	Time (seconds)	Focus-Film Distance (inches)
Skull and Cervical Vertebrae	76	10	2.0	60
Thorax and Shoulder	76	10	1.75	60
Abdomen	76	10	1.75	60
Pelvis and Hip	76	10	2.0	60
Femur and Knee	68	10	2.0	60
Tibia and Fibula	68	10	1.75	60
Foot	68	10	1.5	60

Table 2—Mummy (Wrapped) Not in Cartonnage

Part	Kv	Ma	Time (seconds)	Focus-Film Distance (inches)
Skull and Cervical Vertebrae	65	10	2.0	60
Thorax and Shoulder	65	10	1.75	60
Abdomen	65	10	2.0	60
Pelvis and Hip	65	10	2.0	60
Femur and Knee	60	10	2.0	60
Tibia and Fibula	60	10	1.75	60
Foot	60	10	1.0	60

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The kindness of the radiologists in charge and the staffs of Middlesex Hospital and King's College Hospital, London; Royal Victoria Infirmary, Newcastle; and Dryburn Hospital, Durham, and of the management and staff of Kodak Limited, London, in providing facilities and assistance in processing the radiographs is also much appreciated.

The generous cooperation of Professor J. R. von Ronnen and of his staff, X-ray Department, Akademisch Ziekenhuis, Leiden, and of the staff of Kodak N.V., The Hague, The Netherlands, as well as the help and hospitality of the management of Kodak Pathé, Paris, is gratefully acknowledged.

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