

# Radiology of the Manchester Mummies

by

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## Introduction

Despite the ready acceptance in medical diagnosis of Roentgen's discovery in 1895, little scientific investigation into the value of x-ray technology in Egyptology has been made until recent years. The problems of relatively immobile, dense and heavy objects together with the low-powered equipment and indifferent processing units available for field study seem to have provided significant disincentives.

The first radiographs of mummified material (a child and a cat) were obtained by W. König in the Senckenberg Museum in Frankfurt in March 1896.<sup>1</sup> Amongst 261 various x-rays obtained during 1896 by the English pioneer Thurstan Holland<sup>2</sup> in Liverpool is recorded a mummified bird. The author comments on the picture, dated 22 October 1896, that the 'advantage of this class of subject is that there is no movement'. In 1898, Petrie<sup>3</sup> made use of x-rays in the investigation of human mummified remains and shortly afterwards, in 1904, Elliot Smith, assisted by Howard Carter, x-rayed the mummy of Tutmosis IV<sup>4</sup> (18th Dynasty — c.1575–1308 B.C.). The condition of the epiphyses enabled the age of the King at the time of his death to be estimated with precision.

Moodie,<sup>5</sup> in one of the earliest comprehensive radiological studies, surveyed the Egyptian and Peruvian mummies of the Chicago Field Museum in 1931 and commented that 'Roentgenology supplements all other methods of learning of physical troubles in early times'. Gray,<sup>6</sup> together with various co-workers, has, in a series of systematic radiological surveys at sites in the United Kingdom and Europe since 1960, documented some 193 ancient Egyptian mummies. These include the important collections at the Rijksmuseum, Leiden,<sup>7</sup> The British Museum<sup>8</sup> and the City of Liverpool Museums.<sup>9</sup>

The University of Michigan School of Dentistry over a five-year period in the late 1960s conducted a radiological analysis of the mummies housed in the Egyptian Museum in Cairo.<sup>10</sup> This survey revealed anomalies in the recorded ages at which various Pharaohs died and raised doubts about the genetic relationships amongst members of the ruling families. Detailed radiological studies may contribute significantly to the identification of historical figures<sup>11</sup> and some of the techniques are now well-established in forensic practice.

Most recorded specimens, even in recent years, have been radiographed on site, either in museums or at archaeological sites. The investigation in these circumstances is then significantly limited by the need for mobile compact equipment capable of being attached to local

electricity supplies or associated with suitable isotope sources. Special constraints result from the heavy and dense casing in which specimens are frequently housed combined with the problems of varying density artefacts in the complex wrappings. Neither situation is conducive to accurate reproducibility or comparison with modern material. Such comparative studies will only be feasible if standardized conditions prevail. Even with high-powered equipment, overlying artefacts, wrappings and casings may render detailed analysis difficult.

To investigate radiologically the entire collection of the Manchester University Museum in the near-ideal conditions of a modern hospital Department of Diagnostic Radiology containing orbiting, fluoroscopic and tomographic equipment, presented a unique challenge and an unparalleled scientific opportunity. One mummy (1770) was examined before and after unwrapping, enabling the validity of the methods and results to be established.

This report presents the radiological findings on all the human mummified remains currently housed in the University of Manchester Museum together with an account of the techniques employed.

## Material and Methods

The ancient Egyptian mummified remains at present in the possession of the Department of Egyptology in the University of Manchester consist of 17 complete human mummies and a number of loose human appendages, including five heads and a number of animals and birds.

All specimens were transported individually from the University Museum to the Department of Neuro-radiology, Manchester Royal Infirmary, where appropriate specialized radiological equipment is available (1). This equipment included the Elema Schonander Mimer III radiological unit equipped with a 0.3 mm focal spot x-ray tube capable of orbiting the subject, of fluoroscopy by means of a 7 in. image intensifier and television and of varying sectional thickness tomography at any angle of orbit. An associated high-power generator made it possible to employ fine grain industrial film (Kodak Industrex C) in order to improve image detail. High-speed (90 seconds) and controlled film processing was immediately available. The investigations were carried out at weekends and at night to avoid interference with patient investigation.

Two specimens (Asru and Khary) were also investigated in the University Department of Diagnostic Radiology, Medical School, University of Manchester, by computed tomography (EMI CT5005) — a technique

designed to obtain transverse body sections 5 to 13 mm in thickness.

In the particular case of mummy 1770 a further radiological survey was conducted after unwrapping. This survey enabled detailed radiological observations including macroradiography to be obtained on some of the dissected parts.

Fluoroscopy was carried out on each subject as a first procedure to evaluate the nature of the contents and their disposition. External modelling and decoration on the cartonnage, no matter how elaborate, has no positional relationship to the anatomical remains within (42). Under television control during orbiting manoeuvres, markers were placed on the outer casing to identify

anatomical planes, for example coronal and sagittal, of the human remains within. Particular landmarks, such as the anthropological base line of the skull and the level of the nasion were also located and indicated.

As a routine procedure, a radiographic survey was then obtained in two planes, using overlapping films to include the entire subject (8). These radiographs, together with the observations of fluoroscopy, were then studied to devise a logical and more detailed investigation employing thin section tomography or stereoscopy. The radiographic factors are recorded in Table I.

(For explanation of radiological terminology, see Appendix).

**TABLE I**  
(All radiographs were obtained on Kodak Industrial C film)

Mummy		mAs	kVp	Tomo (Angle°)	f.f.d. (cm)	Tube focus (mm)
21470 (NA)	Skeleton Skull + Tomos	250 64 – 100	65–76	16/31	228 110	1.0 0.3
21471 (KN)	Skeleton Skull + Tomos	80 – 250 64 – 100	65–75	16	110/228 110	0.3 0.3
3496 (Reed Coffin)	AP/Lat Tomos	250 100 – 130	65–75	31	228 110	1.0 0.3
9354 (Khary)	AP Lat Skull Tomos	130 – 250 200 × 2 – 250 × 3 100 × 3 – 200 × 4 40 × 3 – 160 × 2	65–70	10/31	183 183 110 110	1.0 1.0 0.3 0.3
1976.51a	AP Lat Skull Tomos	100 – 250 250 × 2 – 250 × 4 200 130 – 130 × 2	65–70	10/16	183 183 110 110	1.0 1.0 0.3 0.3
10881 (Ta-Aath)	AP Lat Skull Tomos	130 250 × 3 – 250 × 6 100 × 2 – 100 × 3 200	65–70	10/16	183 183 110 110	1.0 1.0 0.3 1.0
1777 (Asru)	AP/Lat Hands + Feet Skull Tomos	120 100 100 × 2 – 100 × 3 80 – 100 × 4	65	16	183 183 110 110	1.0 1.0 0.3 1.0
5053 (Per-en-bast)	AP Lat Skull Tomos Teeth Face	200 × 3 – 200 × 5 250 × 12 – 250 × 18 100 × 4 – 100 × 10 200 × 3 – 200 × 8 200 × 12 200 × 6	65–75	10/16 31	183 183 110 110 110 110	1.0 1.0 0.3 1.0 1.0 1.0

Table 1 — continued

Mummy		mAs	kVp	Tomo (Angle°)	f.f.d. (cm)	Tube focus (mm)
1768	AP	600			183	1.0
	Lat	200 × 15			110	0.3
	Skull	100 × 4 – 100 × 6	65–75		110	1.0
	Tomos	200 × 2 – 200 × 6		12/16	110	1.0
1770 (Wrapped)	AP/Lat	250 – 400 × 2	75		228	1.0
	Tomos	100 – 250 × 2		16	110	0.3
(Unwrapped)	Calcif'n + Bone detail	25 – 50	40–75		110	0.3
	Tomos	25 – 64	65–70	31	110–152	0.3
9319	AP/Lat	250 – 320 × 2			183	1.0
	Skull	100 – 260	45–65		110	0.3
	Tomos	100 – 160 × 3		10/16	110	0.3–1.0
2109	AP/Lat	130 – 400 × 2			152–228	1.0
	Skull	160 × 2	65–75		110	0.3
	Tomos	200 – 400		16/31	110	1.0
1769	AP/Lat	400 – 400 × 6			183	1.0
	Skull	360 – 100 × 4	65–75		110	0.3
	Tomos	320 – 250 × 2		10/31	110	1.0
20638 (Demetria)	AP	200 × 3 – 200 × 5			183	1.0
	Lat	200 × 5 – 200 × 16	65–75		183	1.0
	Skull	100 × 5 – 100 × 12			110	0.3
	Tomos	200 × 2 – 200 × 4		10/16	110	1.0
1767	AP	350 – 800			152	1.0
	Lat	200 × 6 – 200 × 12			183	1.0
	Skull	100 × 4 – 100 × 6	65–75		110	0.3
	Tomos	250 × 2 – 320 × 3		10/16	110	1.0
	Teeth	64 × 2 – 200 × 8			110	1.0
1766	AP	300 × 2 – 400 × 2			183	1.0
	Lat	400 × 2 – 200 × 15	65–75		183	1.0
	Skull	200 × 2 – 200 × 3			110	0.3
	Tomos	250 – 400 × 2		16	110	1.0
1775 (Artemidorous)	AP	400			183	1.0
	Lat	200 × 4 – 200 × 14	65–75		183	1.0
	Skull	200 × 2 – 250 × 2			110	0.3
	Tomos	400 – 250 × 2		16	110	1.0
5275 Ptolemaic Head	Skull	160			110	0.3
	Soft tissue	50	65–80		110	0.3
	Tomo	130		16/31	110	0.3
7740 (Head)	Skull	130	70–75		110	0.3
	Tomos	80 × 3		10	110	1.0
21475	Skull	130			110	0.3
	Tomos	130	65–75	16/31	110	0.3
21474	Foot	80			110	0.3
22940	Skull	130	65–75		110	0.3
	Tomos	100 – 80 × 3		10/31	110	0.3
21476 9384 9428	Left Hand Left Hand Right Hand	80	65	110	110	0.3

TABLE II

Mummy No.	Period	Provenance	Age	Sex	Arms and Hands	PACKING		THORACIC STRUCTURES PRESENT					Evidence of Brain Removal	Opacif'n of IV Disc Spaces	Costal Cartilage Calcif'n	Knee Joint Articular Calcif'n	Vascular Calcif'n	Bladder Calcif'n	OSTEOARTHRITIS			
						Upper Resp'y	Orbits	Thorax	Abdo	Lungs	Pleura	Heart	Pericard'um						CXS	DS	LS	Joints
21470 (NA)	XII Dyn 1900 B.C.	Rifeh	Adult	M	Ext-OT		R	Yes	Yes					Yes					Yes	Yes	Yes	
21471 (KN)	XV Dyn 1900 B.C.	Rifeh	Adult	M	Ext-OT										++				Yes	Yes	Yes	TIP Feet
3496 (Reed Coffin)	XVIII Dyn 1400 B.C.	Gurob	3/12	?	Ext-AT									Yes								
9354 (Khary)	XIX Dyn 1300 B.C.	Unknown	Adult	M	C.P. (L. hand clenched)		R+L	Yes	Yes	Yes	Yes	Yes	Yes	Yes			Yes		Yes	Yes	Yes	Knees Hips
1976.51a	XXI Dyn	Unknown	Adult	F	Ext-IT		R+L		Yes					Yes	+				Yes	Yes	Yes	
10881a (1a-Aath)	XXI-XXV Dyn 1087-656 B.C.	Luxor	Adult	F	Ext-AT									Yes								
1777 (Asru)	XXV Dyn 751-656 B.C.	Thebes	Adult	F	Ext-IT	OP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	+++		Yes	Yes	Yes	Yes	Yes	TIP
5053 (Per-en-bast)	XXV Dyn 751-656 B.C.	Quernah	Adult	F	Ext-IT	R+L	OP	Yes						Yes	+		Yes		Yes	Yes	Yes	
1768	100 B.C.	Hawara	20	M	Ext-AT				Yes										Yes (Schmorl's)	Yes	Yes	Knees
1770	Ptolemaic	Hawara	14	F	C.P.	R+L								Yes (resin)								
9319	Roman	Hawara	2	?	Ext-OT	L		Yes	Yes	Yes	Yes	Yes	Yes	Yes	++		Yes					
2109	Roman	Hawara	2	?	Ext-OT		Yes	Yes	Yes					Yes								
1769	A.D. 130-140	Hawara	3-4	F	Ext-AT	R+L	Yes	Yes	Yes	Yes				Yes	+		Yes					
20638 (Demetria)	A.D. 100	Hawara	Adult	F	Ext-OT				Yes	Yes				Yes			Yes		Yes	Yes	Yes	R Knee
1767	A.D. 100-200	Fayoum	Adult	M	Ext-P	R+L	NP		Yes										Yes			
1766	A.D. 100-200	Fayoum	Adult	F	Ext-OT	?		Yes	Yes	Yes		Yes	Yes	Yes	++		Yes	Yes	Yes	Yes	Yes	MTPs
1775	A.D. 200	Hawara	Adult	M	Ext-P	R+L	Yes			Yes	Yes	Yes	Yes	Yes	++			Yes	Yes	Yes	Yes	Hips

## KEY:

Ext — extended  
 CP — crossed pectoral — arms folded  
 P — palms cover genital area  
 +++ — — — extensive  
 R — right  
 L — left  
 TIP — terminal interphalangeal  
 NP — nasopharynx



## Results

A summary of the results is presented in Table II.

### No. 21470 (Nekht-Ankh) (2 and 3)

Mummy of man, Nekht-Ankh, son of Aa-Khnum, brother of 2147 (Khnum-Nakht), unwrapped in 1907 by Dr Margaret Murray. Possibly an eunuch and aged 60 at time of death. Non-negroid skull. Contents of canopic jars and other material belonging to this brother include brain, larynx, aortic arch and penis.

*General* Incomplete, mainly disarticulated skeleton of adult male. Only a little soft tissue adherent to bones.

*Skull* Vault intact but dorsum sella and right middle turbinate missing (2). No brain tissue remaining. Petrous bone tomography normal. Packing, possibly linen material, in right orbit. Teeth show attrition.

*Upper Limbs* Right hand and part of left hand missing. Residual soft tissue at head of right humerus and left distal radio-ulnar joint. All epiphyses fused.

*Lower Limbs* Both distal tibial shafts contain small sclerotic areas. There is a small cystic lesion in left distal fibula with local bone compaction (3). Of the tarsal bones, on the left only a loose os calcis and talus remain. On the right, these bones are also loose but the remainder, minus the navicular which is missing, are attached to the left forefoot. Both sets of metatarsals and phalanges are complete. There are early degenerative changes at both first metatarsophalangeal joints. Soft tissue remnants are present over both feet, with skin thickening. All epiphyses fused.

*Thorax* Only scapulae, clavicles, body of sternum and manubrium remain. None show abnormality.

*Spine and Pelvis* Only the sacrum and pelvis remain. The pelvis is android in shape and has an acute subpubic arch. The iliac crest apophysis is fused.

*Comment* Remains are incomplete but of an adult male with little residual soft tissue. The missing dorsum sella and right middle turbinate are evidence of brain removal. Sclerotic areas in the lower tibial shafts may represent areas of bone infarction. A detailed discussion of the bony skeleton has been documented elsewhere.<sup>17</sup>

### No. 21471 (Khnum-Nakht) (5-7)

Mummy of a man, Khnum-Nakht, half-brother of Nekht-Ankh (see above), unwrapped in 1907 by Dr Margaret Murray. Possibly early middle-age at death. Negroid skull. Soft tissue in poor condition; less carefully preserved mummy. Well-marked kypho-scoliosis. Two left incisor teeth of the upper jaw are fused. No canopic jars.

*General* Incomplete adult male skeleton, with reconstructed thorax.

*Skull* Skull vault and base intact. Fractures through left zygomatic arch and left mandible are post-mortem. No evidence of brain removal but no intracranial contents identifiable.

*Upper Limbs* Post-mortem fracture of left fifth metacarpal and degenerative changes of the distal interphalangeal joints.

*Lower Limbs* Growth arrest lines are present in the distal tibiae and proximal fibulae. Both feet and ankles are fully articulated, inverted and have some remaining soft tissue. The left foot has a superficial appearance of a 'club-foot' (talipes equinovarus) but only minor degenerative changes are present in the talonavicular and first metatarsophalangeal joints (5).

*Thorax* The thoracic cage has been reconstructed with modern prostheses of the right fourth rib and anterior ends of other ribs on right side. Healed fracture of right tenth rib posteriorly and further fracture (? PM) of left eighth rib.

*Spine* Cervical — Vertebral body C5 missing. Partial fusion of neural arches of C2 and C3 on left with degenerative changes affecting neurocentral and apophyseal joints from C3 caudally.

*Thoracic and Lumbar* — Lumbar spine scoliotic concave to right. Degenerative changes with osteophyte formation present in mid thoracic and lumbar spine.

*Pelvis* Pelvis android with acute subpubic arch.

*Comment* Incomplete skeleton of adult male. Advanced degenerative changes in cervical and lumbar spine present with healed fracture through right tenth rib. The previously described<sup>17</sup> left club foot (talipes equinovarus) is not supported by present normal bony appearances. A detailed discussion of the bony skeleton has been documented elsewhere.<sup>17</sup>

### No. 3496 (Reed Coffin) (6-8)

Mummy of a child, wrapped in reed mat tied with ropes at each end.

*General* Infant in fair state of preservation apart from disruption of head, neck and upper thorax. Infant wrapped in opaque material or bandaging within reeds. Arms extended with hands pronated over iliac fossae.

*Skull* Skull disarticulated and separated from upper thorax. Mandible lies adjacent to thoracic inlet. Deciduous teeth calcifying but not erupted.

*Upper Limbs* Left shoulder disorganized with scapula lying loose and head of left humerus missing. Capitellum at elbow not calcified. Only capitulum in carpus calcified.

*Lower Limbs* Legs slightly flexed at hips and knees. Neither femoral capital epiphysis is calcified. In right knee epiphyses well formed but with growth arrest lines in upper and lower tibiae. Feet together and internally rotated.

*Thorax* Upper thorax disrupted with left ribs 1-4 missing. Sternum and costal cartilages not present.

*Abdomen* No packing evident.

*Spine* Cervical spine missing together with vertebral bodies T1-4. Appearances otherwise normal.

*Lumbar Spine and pelvis* — disc spaces opaque adjacent to end plates.

*Comment* Infant just under three months of age. Evidence of illness in this short life indicated by growth arrest lines.

No. 9354 (Khary) (9–11)

Mummy of a man, with a coffin.

*General* Partially unwrapped mummy in excellent condition lying supine. Arms crossed over thorax, right over left. Hands pronated, left hand clenched.

*Skull* Skull in alignment with trunk, neck extended. Vault shows biparietal thinning and defect in right squamous temporal bone. Midline bone defect in jugum sphenoidale. Falx cerebri and tentorium cerebelli remain. Opaque material possibly resin in posterior fossa would, in the erect position, in part form a 'fluid level'. Calcification in petroclinoid ligament. Teeth show attrition and extensive caries. Rounded well-defined packs in both orbits.

*Upper Limbs* Small, cortical cyst on lateral aspect of midshaft of right humerus.

*Lower Limbs* Legs extended with feet together. Small exostosis on left lower femur. Articular cartilages visible in both hips and knees with good visualization of soft tissues.

*Thorax* Bony cage intact with healed fractures of right eighth and ninth ribs posteriorly and left eighth and ninth ribs in mid axillary line. Pericardium distinctly seen with cardiac remains within. Both lungs present but collapsed. Small, dense opacities between left elbow and chest wall are in wrappings.

*Abdomen* Diaphragm clearly identified with collection of packing material layered peripherally in abdominal cavity. No organs detectable. Linear prevertebral opacity on lateral projections could be aorta and hollow thin-walled structure in pelvis the remains of rectum.

*Spine* Cervical — Neck extended and intervertebral discs opaque.

Thoracic — Upper thoracic kyphosis with minor degenerative changes in mid-thoracic spine. Disc spaces opacified throughout.

Lumbar — Degenerative changes at L1/2 and L4/5 with disc space narrowing. All discs opacified. Increased density is within annulus fibrosus, the nucleus pulposus is spared. Protrusion of annulus into spinal canal is visible at L3/4.

*Pelvis* No evidence of disease. Iliac crest apophyses fused.

*Comment* Well-preserved, partly wrapped male. Early signs of degenerative disease in thoracic and lumbar spine. Biparietal thinning suggests an elderly man. Horizontal layering of cranial contents might indicate mummified body had been erect for some time after embalming. Clarity of heart and lungs remarkable and demonstration of a herniated intervertebral disc in lumbar spine unique.

No. 1976.51a (12–14)

Mummy of a woman, wrapped in modern gauze bandages, together with painted wooden coffin.

*General* Adult female in good condition. Arms extended with hands pronated over inner aspect of thighs. One detached digit within abdominal cavity.

*Skull* Skull straight, neck extended. Vault and base intact. Irregular, rounded opacity within cranial cavity posteriorly suggests residual brain material. Right frontal sinus and both maxillary antra opaque. Teeth show attrition, extensive caries and periapical infection. Maxilla edentulous. Ring opacities, suggesting prosthetic globes, in both orbits.

*Upper Limbs* Left third and fourth fingers and second and fifth middle and terminal phalanges missing. Osteoarthritic changes present in remaining distal interphalangeal joints. Epiphyseal closure complete. Thin layer of soft tissue present over hands.

*Lower Limbs* Legs extended, feet plantar flexed. Left foot internally rotated.

*Thorax* Bony cage intact, costal cartilages faintly opacified. Thoracic cavity filled with homogeneous semi-opaque material. Large, lobulated midline lucency along long axis. No normal tissues identifiable.

*Abdomen* Semi-opaque substance has layered posteriorly in abdomen and pelvis. In the midline is an air-filled tubular structure. No organ packages, and no evidence of incision site. Displaced digit in epigastrium to right of midline.

*Spine* Cervical — Neutral position with disc space narrowing and osteophytosis C4–C7. Intervertebral joints show osteoarthritic changes. Disc spaces not opaque.

Thoracic — Spine straight with anterior osteophyte formation at T10/11 almost bridging disc space. All disc spaces opaque.

Lumbar — Lateral osteophytes present at L3/4 and L4/5 but disc spaces not unduly reduced in height. Intervertebral discs opaque due to calcification in annulus, nucleus pulposus spared.

*Pelvis* Pelvis gynacoid; sacro-iliac margins sclerotic.

*Comment* Adult female with spinal degenerative disease suggesting advancing age. Features for comment are residual brain tissue, well-defined eye globes probably prosthetic, layering of resinous material in abdomen and pelvis, and extensive intervertebral disc calcification.

No. 10881 (Ta-Aath) (15–16)

Mummy of a woman, with a coffin.

*General* Adult mummy in poor, disorganized condition due to previous unwrapping. Arms disarticulated, right flexed and left extended. Both hands disarticulated at wrists and pronated over iliac fossae. Long package present between thighs.

*Skull* Fracture present through sphenoid air sinus, tuberculum sellae on left and base of dorsum sellae. Latter lies in sphenoidal air sinus. Cranial cavity empty. Many teeth missing from maxilla. Left upper canine unerupted and crown directed mesially. Marked dental attrition. Mandible lies separate from skull.

*Upper Limbs* Upper limbs disarticulated at shoulders, elbows and wrists. Humeri lie parallel to chest walls. Right elbow flexed with ulna parallel to humerus. Right radius parallel to left humerus. Fracture through distal right ulna shaft with distal fragment missing. Both hands

separated at wrist joints. Only thumbs complete, the intermediate and distal phalanges of other digits missing. A finger stall is present on right thumb.

*Lower Limbs* Bones disorganized but all approximately in correct position, except left talus which is adjacent to right knee joint. Epiphyseal development complete.

*Thorax* Rib cage jumbled. No contents visible.

*Abdomen* No soft tissue detail.

*Spine* Cervical — Vertebrae jumbled. No disease.

Thoracic — Two vertebrae missing. Upper thoracic vertebrae jumbled. No disc opacification.

Lumbar — Lumbar vertebrae rotated. Horizontal fracture (? PM) through L5 and disc space narrowing at L1/2. Intervertebral discs throughout show irregular opacification.

*Comment* Adult — sex uncertain. Evidence of brain removal through sphenoid in midline. General disorganization and loss of some bones consistent with previous unwrapping.

#### No. 1777 (Asru) (17–20)

Mummy of a woman, with two wooden coffins. The mummy, well-preserved, was already unwrapped when it arrived at the Museum.

*General* Complete, unwrapped, female mummy; excellent state of preservation. Both arms extended with hands pronated over inner thighs. Widespread, dense, particulate matter throughout soft tissues.

*Skull* Discrete lytic defect approximately 1 cm in diameter in right posterior parietal bone. Skull base intact except for detached dorsum sella lying to left and behind its normal position. Convoluting density in occipital region is probably brain. Dural remains present in left middle fossa. Acellularity of right mastoid, suggesting previous infection. Remaining teeth show attrition, with abnormal palatal angulation of upper central incisors. Pack in posterior nasopharynx. No orbital contents.

*Upper Limbs* Left third digit shows ankylosis of proximal interphalangeal joint with distal ulnar deviation. Osteoarthritic changes in distal interphalangeal joints. Arterial calcification present. Opacity in left axilla is in wrappings of chest wall.

*Lower Limbs* Feet together. Lines of arrested growth present in right upper tibia. Reduction in height of medial compartment of right knee with opacification of menisci. Right femoral artery calcified. Soft tissues of feet well preserved with plantar fascia readily visible.

*Thorax* Intact with normal rib cage. Costal cartilages completely opacified. Pericardial remains identifiable together with mediastinal pleura on left but no cardiac or pulmonary tissue identified. Upper mediastinum rotated to left; within it are opaque cartilaginous rings of trachea and bronchi together with aortic arch calcification. Opaque mass present in left thorax.

*Abdomen* Diaphragm intact posteriorly. No packaging present in abdomen and no incision site detectable. Elevated peritoneum in right paravertebral gutter detectable. No kidneys visible.

*Spine* Cervical — Spondylosis marked with generalized disc space narrowing. Osteophyte formation anteriorly and posteriorly with degenerative changes in apophyseal joints. Occipito-atlantal fusion present bilaterally. All disc spaces opaque.

Thoracic — No degenerative changes present. All disc spaces opaque.

Lumbar — Sacralization of L5 with partial collapse of upper border of L3 anteriorly associated with osteophytosis. Extensive disc opacification present. Herniation of annulus posteriorly at L2/3.

*Pelvis* Pelvis gynaecoid and normal.

*Comment* Elderly female with marked cervical and lumbar spondylosis and herniated L3/4 lumbar disc following old trauma to L3 vertebra. Abnormal spinal segmentation at both ends of neural axis. Fracture through dorsum sella indicates removal of cranial contents. Calcification of aorta, tracheo-bronchial cartilages, femoral and ulnar arteries, indicate an advanced age at death. Changes in left third digit probably the result of previous septic arthritis. Defect in right parietal bone could be a metastatic tumour deposit.

#### No. 5053 (Per-en-bast) (21–23)

Mummy of a woman in coffin.

*General* Well-preserved adult, probably female. No evidence of disturbance. Arms extended with hands pronated over inner thighs. Metallic Horus present over mid thorax and metallic incision plate over left lower abdomen with less dense ceramids scarabs in midline above Horus. Metal objects probably gold.

*Skull* Skull straight and aligned with no evidence of brain removal. Opaque falx and tentorium remain. Bilateral carotid arterial calcification at level of pituitary fossa. Dental state poor with attrition, caries and periodontal abscess formation. Dense pack in oropharynx. Opacities in orbits may be packs or prosthetic globes.

*Upper Limbs* No abnormality.

*Lower Limbs.* Right second metatarsal head flattened and left fourth and fifth proximal phalanges shorter and wider than those on right with osteoarthritic changes in both first metatarso-phalangeal joints. Calcification in left femoral and right dorsalis pedis arteries. Soft tissues of feet well outlined.

*Thorax* Rib cage intact and thoracic cavity filled with extensive packing containing speckled, high density material. No normal structures visible. Some of lower costal cartilages calcified.

*Abdomen* Metal plate over left flank indicates embalmer's incision site. Dense packing material in abdominal cavity with at least four separate packs identifiable.

*Spine* Cervical — No abnormality. No opaque disc material present.

Thoracic — Degenerative changes with osteophyte formation in mid thoracic region. Disc spaces not opaque.

Lumbar — Partial collapse of vertebral bodies L1, L4 and L5 with anterior wedging of body of L1. Disc spaces



increased relative to vertebral height with extensive osteophyte formation. Intervertebral discs calcified.

*Pelvis* Gynaecoid in shape. No bony abnormality.

*Comment* An elderly female. Carotid artery calcification is evidence of ageing but there is remarkably little degenerative disease in cervical spine. Lumbar spine shows degenerative change and vertebral body collapse suggesting senile osteoporosis or, less probably, metastatic bone malignancy. Flattening of second right metatarsal head could be result of avascular necrosis or stress fracture. Packing in oropharynx, thorax and abdomen dense and may contain mud. Per-en-bast is the only mummy with metal or ceramic artefacts, i.e. flank incision plate and pectoral Horus.

No. 1768 (24–25)

Mummy of a boy.

*General* Poor state of preservation with disorganization of contents. Arms extended with hands pronated over anterior thighs. Packaging present in left loin. Stiffening board incorporated in wrappings along length of mummy posteriorly with a 'tongued and grooved' joint behind knees.

*Skull* No evidence of brain removal. Irregular dense material in occipital region probably brain tissue. One of mid cervical vertebrae lies in oropharynx and posterior nasopharynx. Pack in anterior nares. Teeth in excellent condition but wisdom teeth all absent.

*Upper Limbs* Both humeral and radial heads dislocated (PM). All epiphyses fused.

*Lower Limbs* Early osteoarthritic changes in both knee joints with sclerosis of tibial plateaux. Cartilage opacification present in knee joints. Upper tibial epiphyses fused.

*Thorax* Bony thorax collapsed. All ribs present although a number are dislocated at costo-vertebral joints.

*Abdomen* Diaphragm present on right. Folded material in left flank indicates incision site. Packing present in left loin.

*Spine* Cervical and Thoracic — Jumbled. No evidence of disease.

Lumbar — Disorganized with disc space narrowing at L1/2 where there is a small Schmorl's node indicating vertebral end plate disease and internal disc herniation.

*Pelvis* Pelvis android with sacroiliac joints dislocated. Iliac crest apophyses partially fused.

*Comment* Young adult male aged 20 in poor state of preservation at embalming though possibly disturbed later. Jointed stiffening board incorporated in wrappings posteriorly. Brain tissue present in cranial cavity. Dental state excellent but third molars absent. Early osteoarthritic changes present in knee joints, unusually so in someone so young. No cause of death demonstrated.

No. 1770 (26–32)

Mummy of an adolescent girl.

PRE-UNWRAPPING

*General* Body in poor condition. Arms folded across

chest, right over left with hands pronated. Prosthetic lower legs and feet.

*Skull* Totally disarticulated but no bone abnormalities. No evidence of brain removal. Spheno-occipital synchondrosis separated. Good dental state with no attrition or decay.

*Upper Limbs* Both shoulders dislocated. Left humeral head missing, both elbows dislocated. Olecranon epiphysis fused but radial head epiphysis unfused. Carpal bones all present.

*Lower Limbs* Right leg amputated 10 cm above knee, remainder of leg missing. Left leg amputated below left knee, 10 cm from upper end of tibia. Left lower femoral epiphysis displaced and left patella missing. Lower legs represented by short prosthetic limbs with prosthetic feet. Canine tooth present by right knee.

*Thorax* Rib cage collapsed with some ribs disarticulated at costo-vertebral joints. Multiple fractures in lower ribs. No thoracic contents detected.

*Abdomen* No evidence of incision site. Diaphragm not visible. Abdomen full of amorphous opaque material with two distinct opacities, one to the right of L3/4 and one to the left of L4/5 in the abdominal wall. Opacity on right has serpiginous structure. False phallus seen at unwrapping evident on review of radiography.

*Spine* Cervical — Spine completely disorganized; vertebral bodies loose in wrappings.

Thoracic and Lumbar — Normal alignment apart from T1/3 segments which are displaced. Linear densities present throughout spine in intervertebral disc spaces.

*Pelvis* Pelvis disorganized with disruption through all synchondroses.

#### POST-UNWRAPPING

*Skull* Maxillary block re-radiographed. Left antrum hypoplastic and left inferior and middle turbinates missing. Mud packs present in both orbits. Teeth show no evidence of attrition. Upper molars unerupted with fracture through right upper incisor.

*Lower Limbs* Irregular bone ends at amputation sites contain compacted mud giving rise to appearance of bone regeneration.

*Abdomen* The two opacities in abdominal wall were subjected to macroradiography. The right-hand one demonstrates the serpiginous outline of a calcified guinea worm.

*Spine* Linear densities of intervertebral disc spaces were confirmed and shown to be resinous material.

*Sandals* No evidence of radio-opaque pigment in paint of the sandals which are therefore assumed to contain vegetable pigment.

*Comment* Poorly preserved 14-year-old female with evidence of skeletal disturbance. Legs have been amputated either at or shortly after death and there is no bone repair or reaction. Hypoplastic left antrum and missing turbinates together with normal teeth might be evidence of chronic upper respiratory tract infection and a prolonged fluid diet. Only evidence of disease is presence of calcified guinea worm in abdominal wall.

No. 9319 (33–35)

Mummy of a child.

*General* Mummy of a child, possibly male, in excellent state of preservation. 92 cm crown-heel length. Arms extended with hands pronated on outer thighs. Some longitudinal support present in wrappings behind head and body.

*Skull* Apart from subluxation at spheno-occipital synchondrosis, the skull is intact and slightly rotated to left. Opaque material present in cranial cavity and layered in occipital region suggests resin. No other evidence of brain removal. All deciduous teeth present; first molars erupted, second molars unerupted.

*Upper Limbs* Ossification of capitate, hamate, distal radial epiphysis and bases of proximal phalanges; remaining wrist bones still cartilaginous.

*Lower Limbs* Legs extended, feet together deviating slightly to left. Lines of arrested growth present in lower femur and lower and upper tibiae. In the hip, both femoral heads and greater trochanters ossified. Cartilage in knees has opacified. Upper fibular epiphysis present in cartilage.

*Thorax* Bony case intact and costal cartilages opaque. All ossification centres in sternum present. Pericardium and pleura visible with some lung tissue on left. Unidentifiable tissue remains in upper mediastinum.

*Abdomen* Abdominal cavity packed, probably with linen though a more dense and more solid package is present in left loin. No evidence of incision site. Diaphragm easily identified.

*Spine* Complete and intact. Acute flexion at C2/3 and C3/4. Odontoid process not yet fused to body of C2. Intervertebral disc spaces partially opaque due to increased density and detachment of end plate cartilages.

*Pelvis* Opacification of acetabular cartilage present. Opaque material present between thighs.

*Comment* Well-preserved child, probably male, aged about two years. (Bone age two years — two years eight months. Dental age 15–24 months.) There is evidence of previous ill-health — cause of death not known. Extensive cartilaginous opacification noted.

No. 2109 (36)

Mummy of a child.

*General* Body of child aged about two years. Sex not known. Crown-heel length 83 cm. Spine and ribs disorganized, suggesting disturbance. Arms extended with hands pronated over outer thighs.

*Skull* Subluxation of spheno-occipital synchondrosis with anterior bone defect through ethmoidal air cells in midline. No intracranial contents remain. Deciduous teeth all present. Dental age just over two years.

*Upper Limbs* Radial head epiphysis not ossified. Appearance of distal radial epiphysis and carpal bones suggest bone age of about two years. Faint opacification of cartilage in joints of upper limb.

*Lower Limbs* Legs extended. Hips show no calcification of greater trochanter epiphysis. Patella not yet calcified nor has the proximal fibular epiphysis. Ankle dorsiflexed and appearance of feet suggests pes cavus.

*Thorax* Ribs markedly disorganized with fracture through right eighth rib. Costal cartilages not opaque. Heterogeneous packing opacities present in right thoracic cavity but no anatomical structures identified.

*Abdomen* Detail of left hemidiaphragm remains, with packing in left flank and pelvic cavity.

*Spine* Cervical — Subluxation at atlanto-occipital articulation with defect of atlas anteriorly. Loss of disc space at C3/4. Spine dislocated (PM) at C7/T1 with neural arch of C7 missing.

Thoracic and Lumbar — Dislocation and lateral angulation at T4/5 and T11/12. Disc spaces partially opaque due to cartilage detachment.

*Pelvis* Apart from lateral compression no other abnormality demonstrated.

*Comment* Disrupted young child. Both bone and dental age suggest two years. Only suspicion of disease is presence of pes cavus bilaterally.

No. 1769 (37 and 38)

Mummy of a child.

*General* Mummy of child age three to four years in good state of preservation. No evidence of disturbance. Arms extended and pronated over anterior aspects of thighs.

*Skull* Subluxation at spheno-occipital synchondrosis and loose bone fragments present in nasopharynx. Left ethmoid sinus partly destroyed but no anterior fossa defect demonstrated. Falx cerebri present in anterior cranial cavity and well-defined packing in orbits. The posterior oropharynx contains a loose molar tooth. Dental age, three to four and a half years.

*Upper Limbs* Lines of arrested growth present in distal humeri. Epiphyseal development at elbow and hands indicates bone age of three years. Cartilaginous structures notably opaque.

*Lower Limbs* Legs straight with feet together. Bones normal except for dense epiphyseal margins in femoral heads and upper tibiae. Cartilage opacification prominent. Suspicion of soft tissue packing in legs.

*Thorax* Thorax compressed with costo-vertebral dislocation on right. Left first rib straightened anteriorly. Costal cartilages faintly calcified. Bilateral lung remains but no evidence of cardiac remains. Well-defined package present in right hemithorax.

*Abdomen* Soft tissue packing in abdominal cavity but no evidence of incision site.

*Spine* Intervertebral disc spaces increased in density in both thoracic and lumbar spine due to detached end plate cartilages. Subluxation of vertebral body C5 on C6.

*Pelvis* Bony pelvis compressed bilaterally.

*Comment* Well-preserved child aged three years, deformed by tight wrappings. No indication of sex. Dense

epiphyseal margins and lines of arrested growth suggest previous illnesses. Packings present in chest and abdomen with evidence of removal of cranial contents through left nostril.

No. 20638 (Demetria) (39 and 40)

Mummy and mummy-case of female.

*General* Adult female in good state of preservation. Arms extended with hands semi-pronated, palms to outer thighs. No artefacts or loose packings.

*Skull* Skull rotated to left. Vault and base intact except for defect in right supra-orbital fissure. Hyperostosis frontalis interna and non-development of frontal sinuses with large ethmoidal air cells. Teeth show attrition and caries. No orbital contents detectable.

*Upper Limbs* No abnormality detected. Epiphyseal fusion complete.

*Lower Limbs* Osteoarthritic changes present in right knee with early lateral osteophyte formation. Meniscal cartilage opacification present on left. Feet reveal claw toes on right fourth and fifth toes and a left pes cavus.

*Thorax* Rib case compressed with right lower ribs disarticulated posteriorly. Lower articular ends of rib cartilages opacified. Remains of right lung identifiable.

*Abdomen* Diaphragm identifiable with heterogeneous opaque material packing abdomen. No evidence of incision site.

*Spine* Cervical — Disc space narrowing C5/6 and C6/7 with subluxation. No osteophytes.

Thoracic — Disarticulation at T7/8 (probably PM). Generalized disc space narrowing with anterior osteophytic lipping from T8–T12.

Lumbar — Scoliosis concave to right with generalized disc space narrowing especially L3/4 on left. No osteophytic lipping.

*Pelvis* Pelvis gynaecoid. Symphysis pubis disarticulated and sacro-iliac joints subluxed.

*Comment* Middle-aged female with evidence of degenerative disease in thoracic spine. Right knee shows early osteoarthritic change with cartilage calcification.

No. 1767 (41–43)

Mummy of a man, in a cartonnage case.

*General* Poorly preserved elderly male with axial skeleton and rib cage disorganized. Arms extended with hands pronated over genitalia, left hand over right.

*Skull* Vault and skull base intact with no defect to indicate brain removal. No intracranial contents visible. Orbits and nasopharynx contain packing material. Mandible disarticulated and displaced posteriorly. Left upper central incisor has been reinserted into right lower incisor socket during embalming.

*Upper Limbs* Post-mortem subluxation of humeral heads. All epiphyses fused.

*Lower Limbs* Legs straight with feet together and left foot internally rotated. Both feet plantar flexed.

*Thorax* Bony cage collapsed with some ribs disarticulated at costo-vertebral joints. Costal cartilages opacified. No thoracic contents present.

*Abdomen* One package present within abdominal cavity but no evidence of incision site.

*Spine* Cervical — Neck acutely flexed and cervical spine disorganized.

Thoracic — Bony spine disorganized especially upper segments. Osteophytes present in mid-thoracic region. Several disc spaces partially opaque due to resin.

Lumbar — Lower lumbar spine rotated with acute lordosis at L5/S1. Degenerative changes at L4/5 on left. No disc opacification.

*Pelvis* Pelvis is android. Sacro-iliac joints subluxed.

*Comment* Poorly preserved mummy of adult male, despite the embalmer's attention to detail represented by the attempted tooth replacement; lumbar spine deformity is ante-mortem.

No. 1766 (44 and 45)

Mummy of a woman.

*General* Supine adult mummy in good state of preservation. Arms extended with hands over outer aspects of thighs. Large package present in sub-pubic region.

*Skull* Skull rotated to left but no bone defect detected. Cranial cavity empty. Linen wrapping present in orbits.

*Upper Limbs* All epiphyses fused.

*Lower Limbs* Legs extended with feet together deviated to left; left foot inverted. Left lateral femoral condyle flattened and articular cartilages in both knee joints faintly opacified. Evidence of pes planum (flat feet) with early degenerative changes of first metatarsophalangeal joints.

*Thorax* Bony thorax complete with dislocation of right ninth to eleventh costo-vertebral joints. Costal cartilages opaque. Pericardium but no cardiac tissue identified. Right lung present.

*Abdomen* Diaphragm present but no incision site identifiable. No discrete organ packages but upper abdomen filled with packing material, probably linen. Discrete opacity in packing to right of L3/4. A linear triangular density in pelvis could represent bladder calcification.

*Spine* Cervical — Subluxation at atlanto-occipital and C5/6 levels. No degenerative changes. Disc material not opaque.

Thoracic — Loss of normal kyphos with an unusually straight back. Minimal anterior osteophytosis in lower thoracic spine.

Lumbar — Mild scoliosis concave to right. Disc spaces generally reduced with forward slip of L1 on L2. A lateral osteophyte present on left at L4/5. Intervertebral disc spaces partially opaque but with preservation of nucleus pulposus at L3/4.

*Pelvis* Fractures through left superior and inferior pubic rami together with dislocation of left sacro-iliac joint. Pelvis gynacoid. Osteophytic lipping superiorly at symphysis pubis.



*Comment* Mummy of an adult female. Fractures through pelvis show no evidence of healing and could have occurred immediately before, or after, death. Loss of thoracic kyphos is unusual.

No. 1775 (Artemidorous) (46–48)

Mummy of a man.

*General* Supine male adult with evidence of disturbance. Several ribs, including the right first rib, are in the lower thoracic cavity. Arms are extended with hands over genitalia. One opaque pack present in lower thorax.

*Skull* Skull rotated to right. Vault normal but fracture through left frontal sinus. Evidence of brain removal with defect in right ethmoid. Layered opaque material, probably resin, in occipital region. Teeth show attrition except [678. Edentulous mandible eroded on left by continual impact of upper teeth. Eye packs containing flecks of dense material present bilaterally. Facial profile shows a 'hook nose'.

*Upper Limbs* All epiphyses fused.

*Lower Limbs* Both legs extended with left foot externally rotated. Early osteoarthritic change present in both hip and knee joints. Menisci in knee joints opaque.

*Thorax* Fractures of right 2–6 and left 3–4 ribs. Right first rib lies in lower right thorax. Costal cartilages opaque and fragmented lying in lower thorax with rib fragments. Pericardium and pleura present with remains of left lung. Dense, well-defined pack present in right hemithorax.

*Abdomen* Diaphragm present. No evidence of incision site or packing. Curvilinear pelvic calcification above symphysis pubis probably in bladder. Ante-mortem fracture through right acetabulum extending on to pelvic brim.

*Spine* Cervical — Neck extended with osteoarthritis of apophyseal joints.

Thorax — Kypho-scoliosis and post-mortem distraction at T8/9 with marginal osteophyte on right. Disc space between T9/10 narrowed.

Lumbo-Sacral — Scoliosis with rotation at thoracolumbar junction. Generalized degenerative changes present with disc space narrowing of L3/4, osteophytosis at L1/2 and L2/3 and forward slip of L5 on L4.

*Comment* Adult male with pelvic fracture resulting from severe trauma. Degenerative changes in spine and hips indicate ageing. Bladder calcification could be due either to schistosomiasis or tuberculosis.

No. 5275 (Ptolemaic Head) (49 and 50)

*General* Loose head with soft tissues over skull, face and back of neck.

*Skull* Skull vault intact but defects in base. Dorsum sella fractured at the base and displaced above right petrous bone. Bone defects in left tuberculum sella, anterior pituitary fossa and mid-line cribiform plate. Nasal septum and turbinates missing. During examination a radio-opaque catheter was introduced through the

cribiform plate defect. No orbital contents present. Teeth show attrition.

*Cervical Spine* Only C1–C6 vertebral bodies present but lower two intervertebral disc spaces show signs of degenerative disease with posterior osteophytic lipping. Hyoid bone still in situ.

*Comment* Skull and cervical spine with soft tissue residue demonstrating anterior fossa defects indicative of brain removal. The dorsum sella fracture and displacement due to embalming technique.

No. 7740 (Head (opened) and upper cervical vertebrae)

Head flexed at cranio-vertebral junction and cut cleanly circumferentially around the vault. Skull base intact. Falx visible together with tentorium and dura in parietal region. Brain remnants present in parieto-occipital region. Orbital packs present. Dental state poor with extensive caries, periodontal disease and missing teeth. Heads of mandibles show marked degenerative change with left temporo-mandibular joint dislocation.

Cervical spine extended with degenerative changes in apophyseal joints from C3 to C5. Spine below this level is missing.

Nos. 21475 and 21474 (Head, upper cervical spine and foot)

Skull vault intact. Left frontal sinus hypoplastic. Defect in left anterior clinoid process and dorsum sella. Bone fragment in posterior fossa on left side. There are no dural remains but opaque material present in the parieto-occipital region. Packs present in orbits, oropharynx and nasopharynx. A loose, carious tooth is situated in the hypopharynx.

Upper cervical spine to C3 present and apparently normal.

Foot disarticulated through tibiotalar joint. Acute dorsiflexion of fifth proximal phalanx with fracture through its base. Degenerative changes present in the first metatarsophalangeal joint.

No. 22940 (Head and cervical spine)

Head flexed at craniovertebral junction. Skull vault and base intact. There are remains of the tentorium and interclinoid ligaments. Opaque tissue, probably brain, present in right parietal region. Horizontal fractures through three of the upper incisors and caries in both upper 7s.

There is evidence of petromastoid inflammatory disease. The air cells are small and with surrounding bone sclerosis.

Cervical spine extended and scoliotic (concave to right). Neural arch of C7 missing. Degenerative disease evidenced by apophyseal joint sclerosis from C4–6.

No. 21476 (Hand)

Left hand and incomplete wrist (lunate, triquetrum and part of scaphoid missing) of an adult. Thumb adducted and little finger dorsiflexed. Part of terminal tuft of third terminal phalanx missing, probably post-mortem. Small round opacity noted on palmar aspect of fifth metacarpophalangeal joint.

No. 9384 (Hand)

Complete left hand from radiocarpal joint with fingers in slight flexion. No degenerative changes. Epiphyses closed with closure lines still visible. The bones are well developed and suggest the hand of a young adult male.

No. 9428 (Hand)

Complete right hand from radiocarpal joint with fingers slightly flexed. Post-mortem fracture through head of second metacarpal. Proximal phalanx of thumb fractured with distal fragments missing. Mid portion of second proximal phalanx also missing. Osteoarthritic changes with osteophyte formation present at distal interphalangeal joints. Hand probably of an older male.

## Discussion

There are two main categories of interest in the radiological investigation of ancient human remains. One is concerned with the archaeology and preservation of the specimen and their relationship to the time scale of cultural development, the other with the scientific study of morbidity and mortality in ancient civilization. The term palaeopathology is employed for the study of disease in ancient human remains.<sup>12</sup>

Evaluation of Egyptological collections in museums presents difficulties since material is usually drawn from such an extended time scale. Comment in individual specimens is therefore frequently anecdotal and dependent upon comparison with slowly accumulating data from parallel studies. The 17 complete human mummies in Manchester cover a time scale from 1900 B.C. to c. 4th Century A.D. and have a reported provenance from Hawara to Thebes.

**Age** Radiology presents a unique opportunity to evaluate skeletal maturity and development. Ossification of bone begins at certain main centres about the eighth intrauterine week and progresses at some sites into adult life. After birth, bony epiphyses develop at one or both of the cartilagenous ends of long bone. When growing bones have reached adult length the epiphyses fuse with the remainder of the bone. The time scale for bony development varies in different parts of the body. Fusion of skull bones may not take place until adult life. The skull of a child may therefore readily collapse after death. Some 100 ossification centres could be considered in skeletal assessment but as a basis, six body sites are important — hands, feet, elbows, knees, shoulders and hips. Due to overlying structures and varying posture much detailed tomographic study may

be necessary to ensure a proper evaluation of bony development (7, 8, 28, 34, 35).

Well-documented European and North American radiological standards exist<sup>13, 14</sup> and have been used in the present studies to define bone age. There are, however, significant racial differences related to genetic and nutritional influences with a general tendency towards earlier skeletal maturation in ancient Egyptians. To be truly accurate radiological studies should be from the same ethnic group and from a contemporary population.

Tooth calcification and development, though subject to the same variations and constraints of interpretation, also offer significant information about individual age.<sup>15, 16</sup> Tomography in specially contrived planes calculated from the skull radiographs has been necessary to render such data accessible.

It was possible in the present studies to assess skeletal and dental maturity with reasonable accuracy in all six of the mummies where death had occurred during active growth. The calculated age in this sub-group ranged from three months to 20 years (Table II). The age of the remaining adult mummies could only be assessed subjectively, based on various ageing processes, for example osteoarthritis and arterial calcification (12, 17, 19, 23).

**Sex** In some mummies it was possible to determine sex by direct visualization of the genitalia. In others it was necessary to evaluate the size and shape of the pelvis, skull and appendicular skeleton. No discrepancies from the available descriptions were observed. A direct skeletal study of the remains of the two brothers KN (21471) and NA (21470) in 1907<sup>17</sup> had drawn attention to the eunuchoid features of NA (21470). These observations were confirmed by the present re-examination.

**Embalming** The process of mummification developed over the centuries from pre-dynastic dessication in hot sand to elaborate, stylized, ceremonial in the later dynasties, reaching a peak at the XXIst Dynasty with a subsequent decline towards the Roman period. As a generalization, the later the period after the XXIst Dynasty, the more the attention given by embalmers to the exterior wrapping and less to the treatment of the body within. It might be anticipated that the current study would reveal a wide variety of skeletal and soft tissue changes.

Position of the arms and hands may, together with the general disposition and organization of the other remains, be significant in assessing chronology. The position of the arms and hands on radiographs of 111 mummies were reviewed and evaluated by Gray in 1972.<sup>18</sup> The corresponding information in the Manchester mummies is given in Table II. Most mummies from the XXIst to the XXVth Dynasties have extended arms. The crossed pectoral position of one arm in 10881 is unusual. The remaining arm positions are all consistent with the descriptive dates and the known embalming procedures.

The essential process of mummification consisted of dehydration and desiccation. The abdomen was opened usually by a left flank incision and the abdominal viscera and lungs then removed. Before the XXIst Dynasty the viscera were often placed in four canopic jars. After this

period the viscera might be returned to the body cavity in at least four separate packs. The body and viscera up to the XXVth Dynasty were treated with natron (a mixture of sodium bicarbonate and sodium carbonate) as a dehydrating agent.<sup>19</sup> Later more reliance was placed on the use of resin applied in a molten state when, in the words of Dawson, it might 'invade every crevice of the cavity and even the cancellous structure of bone'.<sup>20</sup> In Roman times, Natron was often used again. Body cavity packing materials varied from sawdust to linen and mud. In the present series by the use of tomography it has been possible to distinguish parcels and packing material of heterogeneous and varying density in the abdominal cavity in ten specimens and in the thoracic cavity of five. Resinous material was clearly identified in the body cavity of 1976.51 (14) and the skulls of 9354, 9319, and 1775.

**Restorations** The soft tissues of the face, trunk and limbs from the XXIst to the XXVIth Dynasty were on occasion restored by subcutaneous packing via small incisions.<sup>8</sup> This type of packing is present in mummy 1769. No definite radio-opaque artificial eyes<sup>21</sup> have been identified in the present series but some form of packing has certainly been identified in nine, possibly ten, specimens. A ring-like opacity revealed by tomography in the orbits of two mummies (1976.51 and 5053) suggests that these particular restorations may be material other than mud or linen, perhaps ceramic, though unusual objects including 'small onions'<sup>24</sup> have been employed (13).

A number of more spectacular embalmers' restorations have been recorded by Elliot Smith and Wood Jones<sup>22</sup> and in the Durham mummy by Gray<sup>23</sup> and again by Gray in Leiden mummy number 24.<sup>7</sup> In mummy 1770 here recorded and the subject of the Manchester unwrapping in 1975, in addition to orbital packs extensive restorations had been undertaken by the embalmer to provide prosthetic lower legs and feet with decorative sandals and gold toe stalls (28, 32). A false phallus was also present.

A simple if inaccurate restoration has been attempted in mummy 1767 by the replacement of an upper incisor tooth in the empty socket of a lower incisor (42). A supporting wooden board is identifiable in 1768, contained within the wrappings. A similar board was noted in Leiden mummy No. 22.<sup>7</sup> In the present specimen a form of tongued and grooved joint is visible.

In brain removal during embalming as described by Herodotus,<sup>24</sup> instrumentation was carried out through the nostrils to avoid disfigurement. Details of the instrumentation and technique have been described by Leek.<sup>25</sup> Evidence of brain removal was sought in the present investigations by detailed thin section tomography together with stereoscopy of the thin ethmoidal plates separating the nasal cavity from the anterior cranial fossa. Such indisputable evidence was obtained in seven of the intact mummies and in one of the decapitated heads. The presence of such characteristic bone defects was detected in mummies ranging from the XIIth Dynasty to the Roman Period (Table II). The dorsum sellae was detached in three (21470, 1777 and 5275) (2, 50). A modern radio-opaque Kifa catheter was introduced

through the defect in 5275 in an attempt to dislodge the detached dorsum adherent in resin (50). The attempt recorded radiologically recalls the similarity of modern neurosurgical approaches to the pituitary fossa by the Chiari approach.

Tissue considered to be residual brain has been demonstrated in several mummies (1976.51, 1777, 1768, 7740, 1764), though tissue characterization cannot be certain (12). Evidence that brain tissue can be preserved is afforded by a recent computed tomographic examination of a shrunken ancient Egyptian brain.<sup>26</sup> This examination revealed ventricular cavities together with grey and white matter discrimination in a 3200-year-old mummy.

**Intervertebral Disc Opacification** Controversy surrounds the aetiology of intervertebral disc opacification in Egyptian mummies. The radiological observation was first recorded by Simon and Zorab<sup>27</sup> in 1961 and a further case added in 1962 by Wells and Maxwell.<sup>28</sup> The changes were attributed by both groups to Alkaptonuria. Alkaptonuria is a rare, inborn error of tyrosine intermediary metabolism in which the enzyme homogentisic acid oxidase is absent. The inability to metabolize homogentisic acid is an autosomal recessively inherited defect which gives rise to the accumulation of homogentisic acid in the urine, which becomes dark on standing, and also to the accumulation of a dark ochre pigment, both intra and extra cellularly, in a variety of connective tissues. The condition is sometimes described as Ochronosis. Joints become arthritic and calcification occurs in intervertebral discs and articular cartilages. In 1967, Gray<sup>29</sup> reviewed 64 mummies from British museums with specific reference to the radiological appearances of the intervertebral disc spaces. Calcification was observed in 18, an incidence of less than one in four. Because of this unexpected frequency together with the absence of any associated osteoarthritic lipping, the appearances were attributed to artefacts of embalming technique. The appearances also coincided closely to the use of natron as an embalming procedure. Attention has been drawn earlier to the changing use of natron and resin in embalming materials. In the present series, ten mummies (six adults and four children) out of seventeen showed evidence of disc space opacification (11, 18, 20, 22). A further two specimens exhibit linear opacification considered to be due to resin within the disc space (29). This last observation was confirmed in one specimen (1770), following unwrapping. Calcification was also observed in the articular cartilage of the knee joints of six mummies (Table II). The remarkable incidence of disc opacification (12 out of 17) adds further doubt to the role of Alkaptonuria as an aetiological factor. Recent biochemical observations, however, have contributed further to the controversy.<sup>30</sup> Ochrotonic pigment has been identified from bone biopsy specimens retrieved from Harwa, a 3500-year-old Egyptian mummy which radiologically exhibits calcified intervertebral discs and is presently housed in the Field Museum in Chicago. Furthermore, recent biochemical and clinical surveys of infants in Slovakia (Eastern Czechoslovakia)<sup>31</sup> and in Wales<sup>32</sup> have revealed a much higher incidence of Alkaptonuria (1 in



25,000 and 1 in 44,800 respectively) than the 1 in 5 million previously anticipated. It is our intention to carry out biochemistry of bone biopsy material from the Manchester mummies in a further attempt to elucidate this problem.

**Arthritis** Degenerative arthritis in both axial and appendicular skeleton as a manifestation of ageing is evident to some extent in almost all the mature adult mummies in the Manchester collection (12, 19). Evidence of degenerative disc disease is present in seven with osteophytic lipping. A Schmorl's node was detected in the lumbar vertebral body of one (1768). Sagittal tomography of the spine in mummies 9354 and 1777 revealed herniation of the calcified annulus at L3/4 (11, 18) — surely the first direct evidence of disc herniation from an ancient civilization. No evidence of ankylosing spondylitis has been detected in the spine or sacro-iliac joints of the 17 mummies examined and we are inclined to support the view<sup>33</sup> that previous descriptions of ankylosing spondylitis have included osteoarthritis.

**Trauma** Post-mortem trauma can often be inferred readily by the site and character of bone damage (2109) (36). Other fractures have classical ante-mortem features. Two specimens (1766 and 1775) here recorded exhibit the typical features associated with a pelvic fracture involving the acetabulum (45, 48, 54). The absence of any radiological features of healing suggest that both were terminal events. Several healed rib fractures have been demonstrated but no other skeletal sites investigated revealed any evidence of healed fractures. The cut surfaces of the amputated lower limbs in mummy 1770 were denser than normal, raising the possibility of new bone formation but the appearances were demonstrated at tomography and confirmed at unwrapping to be the result of impacted mud (28). The mechanism of amputations in 1770 and the time relationship of the events to death remain in doubt. In view of the possibility that the mummy had been immersed in water and the probability of later rewrapping together with the embalmer's attention to detail, crocodile, hippopotamus and shark bites have all been considered. The first is improbable since disarticulation is more likely from crocodile bites; the last two remain possibilities — particularly if sea-water immersion is considered.

**Generalized Disease** Evidence of generalized disease is frequently reflected in the skeleton. Demineralization of the axial skeleton in mummy 5053 together with the partial collapse of vertebral body L1 (22) suggests a menopausal or senile osteoporosis. The absence of localized lesions elsewhere whilst not totally excluding metastatic deposits or myeloma certainly does not support either diagnosis.

Lines of arrested growth, or Harris lines,<sup>34</sup> as seen in 21471, 3496 and 1777 (4, 7), are the result of calcium continuing to be laid down close to the growing ends of bone when bone growth has been temporarily arrested by generalized illness. Although some absorption of Harris lines may occur during childhood, their presence is some indication of morbidity during growth.<sup>35</sup>

Arterial calcification is usually associated with degenerative vascular disease and the ageing process. It is well-displayed in 9354, 1777 and 5053 (17, 23). There is no definite radiological evidence in these three specimens to suggest any abnormality of calcium metabolism though the calcification in 5053 is particularly widespread and dense. Similar calcification is well-described in other Egyptological specimens.<sup>36, 37</sup>

**Biparietal Thinning** Thinning of the parietal bones of the skull vault observed in mummy 9354 (9) is uncommon but not rare. Loss of bone from the outer table of the skull vault has occurred. The radiological appearances are characteristic of the condition. A number of examples have been described in the skulls of ancient Egyptians.<sup>4, 38, 39</sup> The exact aetiology of the condition is unknown but the condition is most frequently associated with ageing. The possible relationship with the wearing of heavy wigs or carrying of heavy water jars has been largely discounted.<sup>39</sup>

**Congenital Anomalies** The presence of a left-sided club foot — talipes equinovarus — in 21471 (KN) was suggested in 1910<sup>17</sup> but the radiological normality (5) noted by Brothwell<sup>40</sup> and confirmed in this study does not support the diagnosis.

**Infection** The only residual evidence of bacterial infection in the present radiological study is in the bony ankylosis of the interphalangeal joint of the left third finger in mummy 1777 (19). There is, however, strong radiological evidence of pathogenic parasites in three specimens. Characteristic serpiginous calcification in the abdominal wall of 1770 is diagnostic of guinea worm (*Dracunculus Medinensis*) infestation (30). The male guinea worm dies and calcifies frequently in this fashion. The female guinea worm is very long (up to 1.5 m) and works its way through the tissues to the skin surface, usually on the foot, in order to discharge the larvae into water. The worm is classically removed by winding on a stick. The 'fiery serpent' which afflicted the Children of Israel in the flight from Egypt and the 'brass rod' of Moses<sup>41</sup> are considered to be a contemporary, if allegorical, description of this infestation and its cure.

Infection with *Bilharzia haematobium* (*Schistoma haematobium*) is widespread in present-day Egypt with the water snail acting as an intermediary host. The adult female worm migrates to the pelvic veins where the ova are laid in the wall of the bladder. The sharp spines of the ova give rise to chronic irritation and calcification in the bladder wall is a frequently-observed radiological feature. The linear calcification in residual bladder tissue observed in 1775 and 1766 is strong evidence of this parasitic infestation (45, 48).

#### Acknowledgements

The authors wish to acknowledge the support and encouragement of Dr Rosalie David and the Manchester Museum Committee in enabling this radiological survey to be carried out. They would also like to thank Kodak Ltd for generous financial support.

Thanks are also conveyed to Mrs M. Tipton and Mrs K. Hale for expert secretarial assistance.

## Appendix

**X-Rays** X-rays belong to the electro-magnetic spectrum, as do light, radio, and television waves. They have the same properties as physical light and obey the same physical laws but their wavelength is much shorter rendering them invisible to the eye. X-rays are produced when a stream of electrons from a heated filament strike a suitable target material. A high-tension electric current attracts the electrons from one to the other. Variation of the speed and quantity of electrons will in turn affect the quantity and penetrative quality of the x-ray beam produced. The region of the target where x-rays, and incidentally heat, are produced is called the focal spot and since sharp shadows are needed this spot must be as small as possible, preferably less than 1 mm square. This is particularly so when any degree of magnification is present in the image.

When an x-ray passes through an object it is differentially absorbed or attenuated by the varying materials making up the object. The degree to which the absorption takes place is dependent on the density and atomic number of the material. The higher the atomic number, the greater the absorption. Bone or metal, therefore, absorb more x-rays than soft tissue or air. Those x-rays ultimately transmitted through an object may be recorded on special photographic film. The resultant radiograph represents; therefore, a 'shadowgram' related to the different absorption characteristics of the materials making up the object. Dense materials appear white, less dense materials varying shades of grey to black.

**Fluoroscopy** If a beam of transmitted x-rays is allowed to reach a fluorescent screen then an immediate and dynamic view of events by the observer is possible. Such a fluoroscopic image is usually amplified in brightness by an image intensifier which in turn may be linked to a closed-circuit television system. It is then possible either to view moving parts in the living or to obtain a conceptual, three-dimensional image of a stationary object by moving it in the x-ray beam. Cine or video recordings of the TV image are standard practice in modern hospital departments.

**Orbiting Equipment** Detailed investigation of brain disorders in the living have led to the development of specialized radiological equipment capable of orbiting the subject. Complex engineering has enabled a fine focal spot (0.3 mm square) x-ray source together with a suitable imaging device to be placed at opposite points on the surface of an imaginary sphere of known radius at the centre of which a region of interest can be placed. The observer is then enabled to view the x-ray image by TV link from an infinite number of aspects without moving the subject. Particular radiographic projections to display detailed features on film may be selected by this method.

**Tomography** The 'shadowgram' nature of the conventional radiograph, no matter how it is obtained, may

result in features of interest being partially or completely obscured by under- or over-lying structures. Tomography is a method of obtaining x-rays of a section or slice of tissue in a plane of interest. The result may be achieved by blurring out unwanted shadows above and below the plane of interest, the image of which is then left sharply defined. Selected blurring of this sort is carried out by controlled movement of the x-ray tube and film in equal and opposite directions about the fulcrum. Structures in the plane of the fulcrum will remain unblurred by the movement. The extent of movement which may be very complex governs the thickness of the unblurred or focal plane. Slices of tissue 1–2 mm in depth may be achieved in this way.

Such tomographic facilities if combined with orbiting apparatus and television viewing afford a variable and sophisticated method of conducting a radiological examination. Units with these capabilities are expensive and usually only located in highly specialized departments of Diagnostic Radiology.

**Computed Tomography** Computed Tomography is an x-ray transmission technique where the x-ray beam is highly collimated and the radiographic film replaced by scintillation or ionisation detectors. The system enables cross-sections of an object to be calculated from precise measurements of transmitted radiation intensity. The transmission data is processed by a computer and presented as a numerical print-out. Digital to analog conversion and appropriate grey-scaling enables the large amount of numerical data to be presented as a pictorial display on a television monitor.

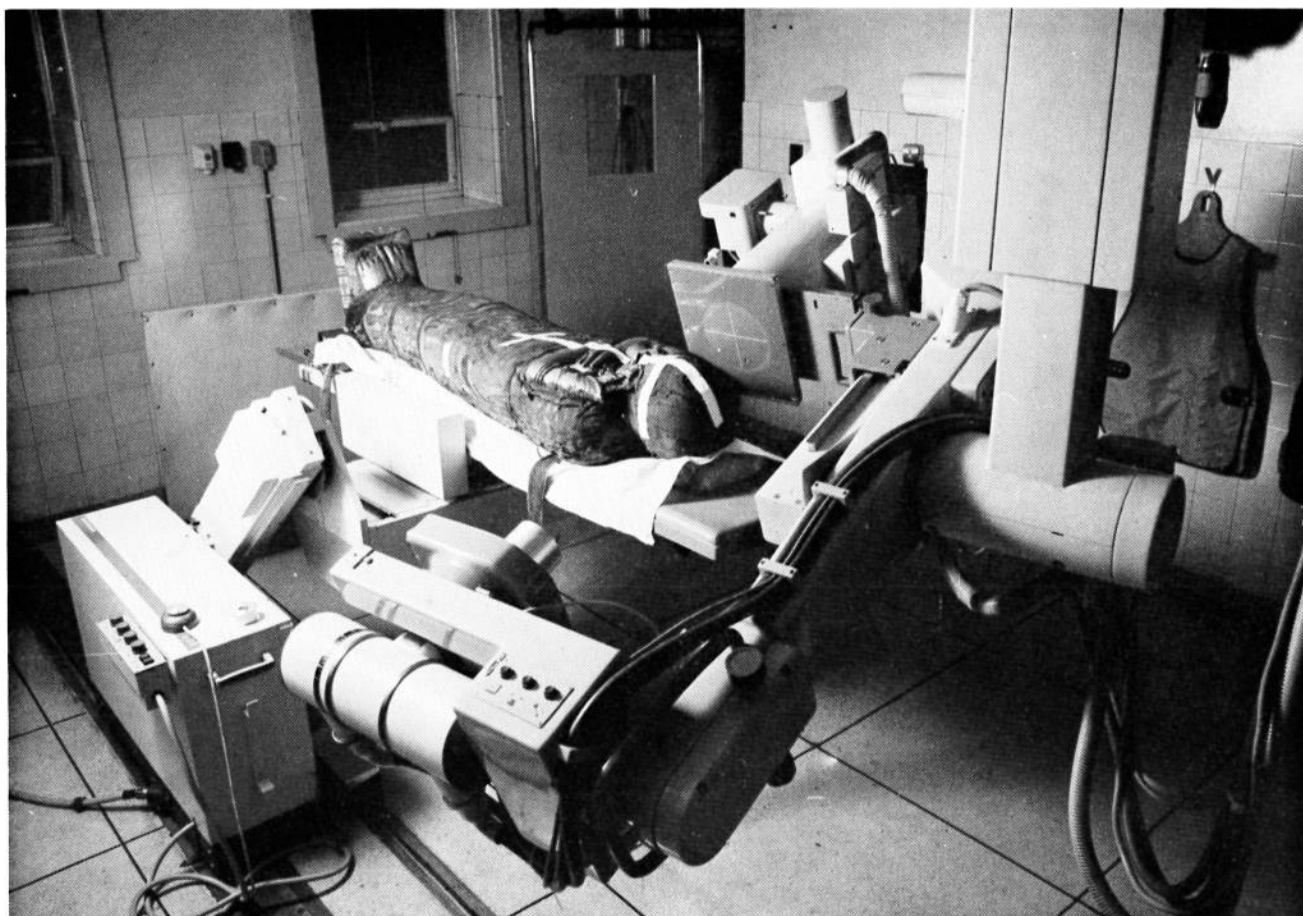
Computed Tomography not only eliminates the problem of superimposition but also enables quantitative interrogation of both normal and abnormal structures which may not be visualized by plain radiography or conventional tomography.

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(1) (Above) Specialized radiological equipment used to investigate all the Manchester mummies in the Department of Neuro-radiology



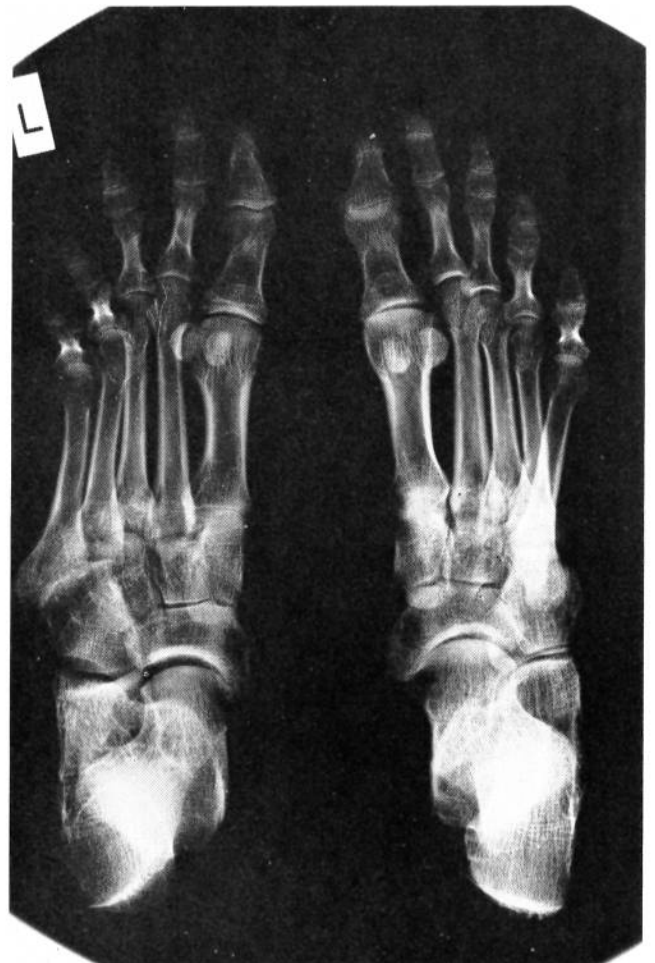
(2) 21470 (NA). Lateral skull.  
Dorsum sella missing. Note attrition of teeth.



(3) 21470 (NA). Ankles. Sclerotic zones distal tibiae? bone infarction (straight arrow). Cystic lesion distal left fibula (curved arrow).



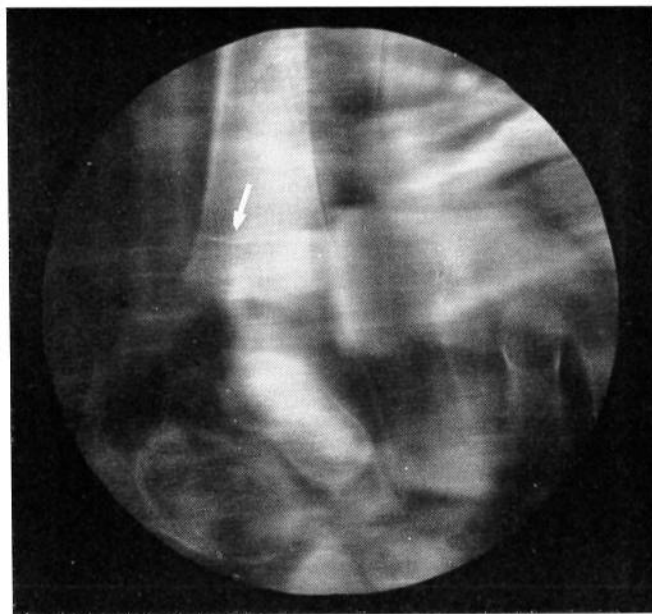
(4) 21471 (KN). AP lower legs. Growth arrest lines (arrow) distal tibiae and proximal fibulae.



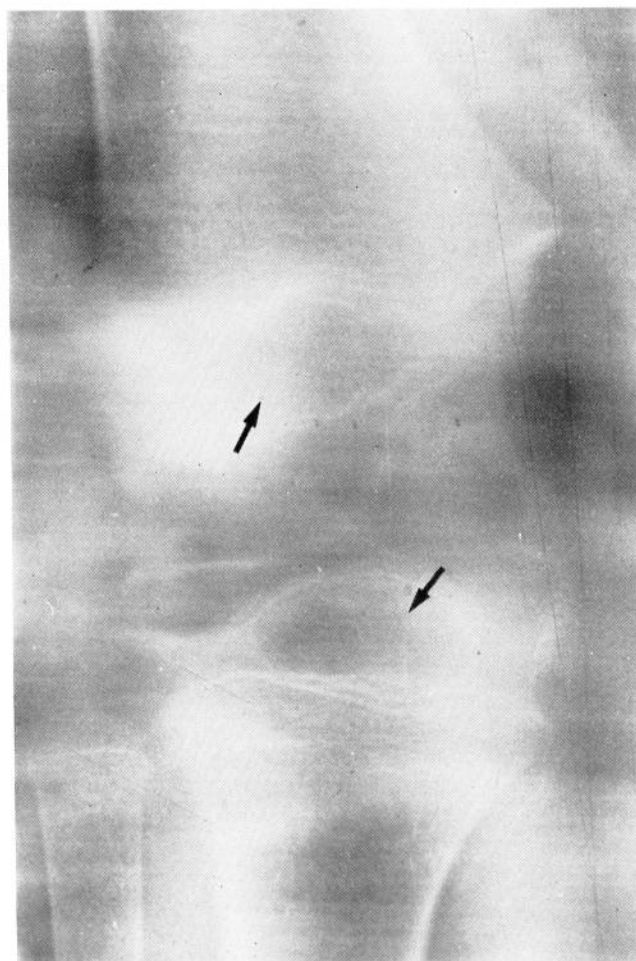
(5) 21471 (KN). AP feet. Club foot deformity was suspected. No radiological abnormality. Appearances due to tight bandaging.



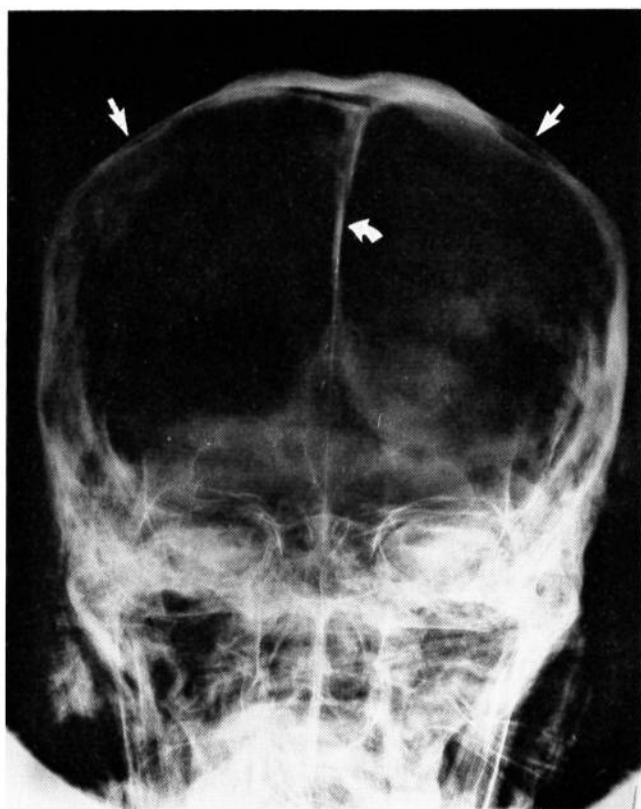
(6) 3496. Preliminary radiographic survey with overlapping films.



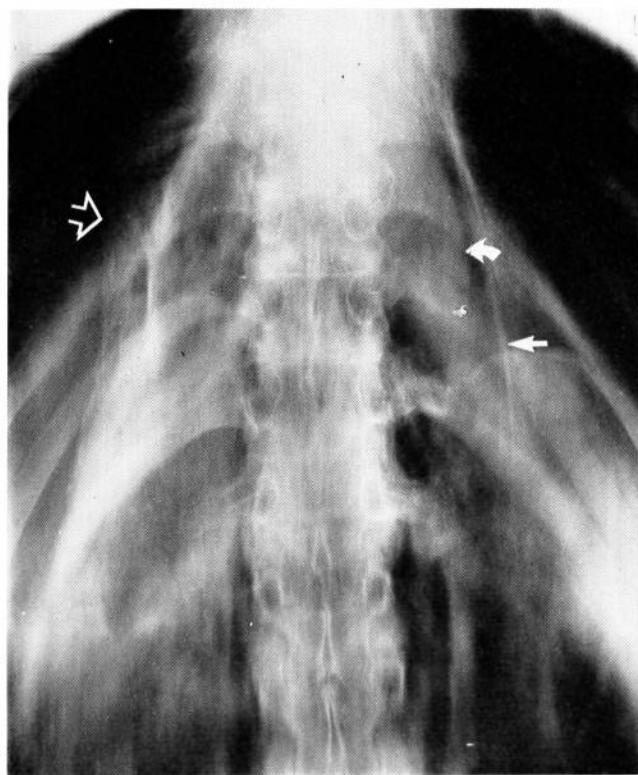
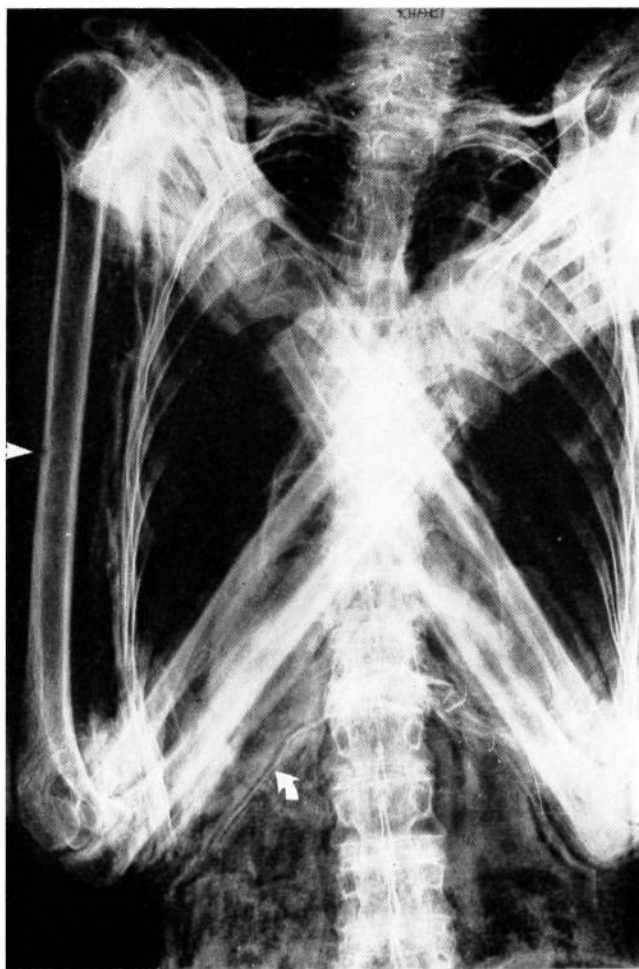
(7) 3496. Lateral tomography ankle and foot demonstrating bone development and lines of arrested growth (arrow).



(8) 3496. AP right knee demonstrating epiphyseal development at distal femur and proximal tibia (arrow). Age just under three months.



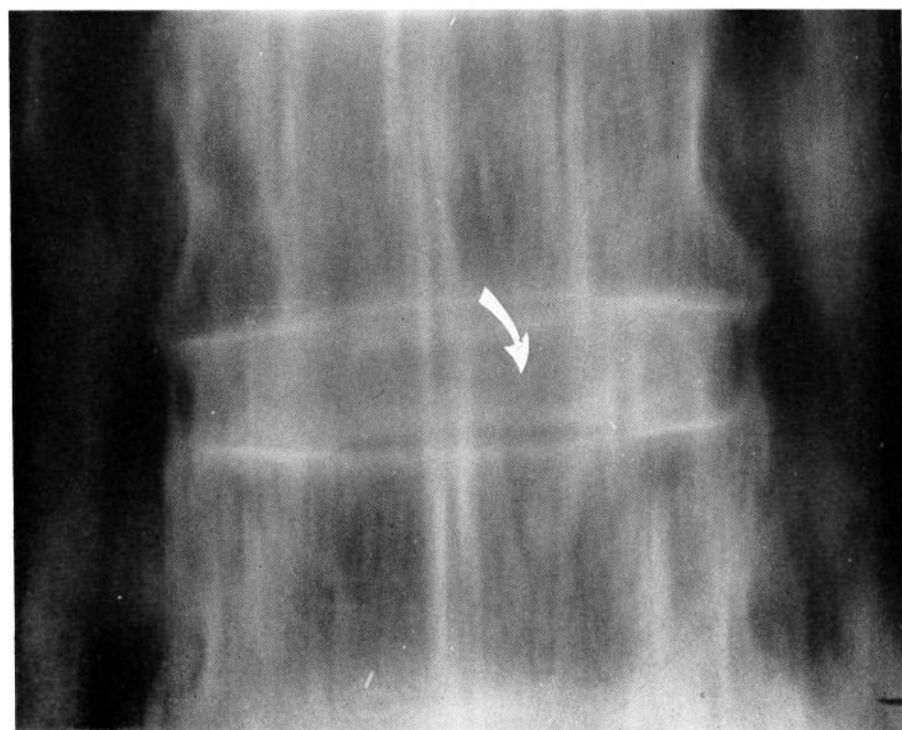
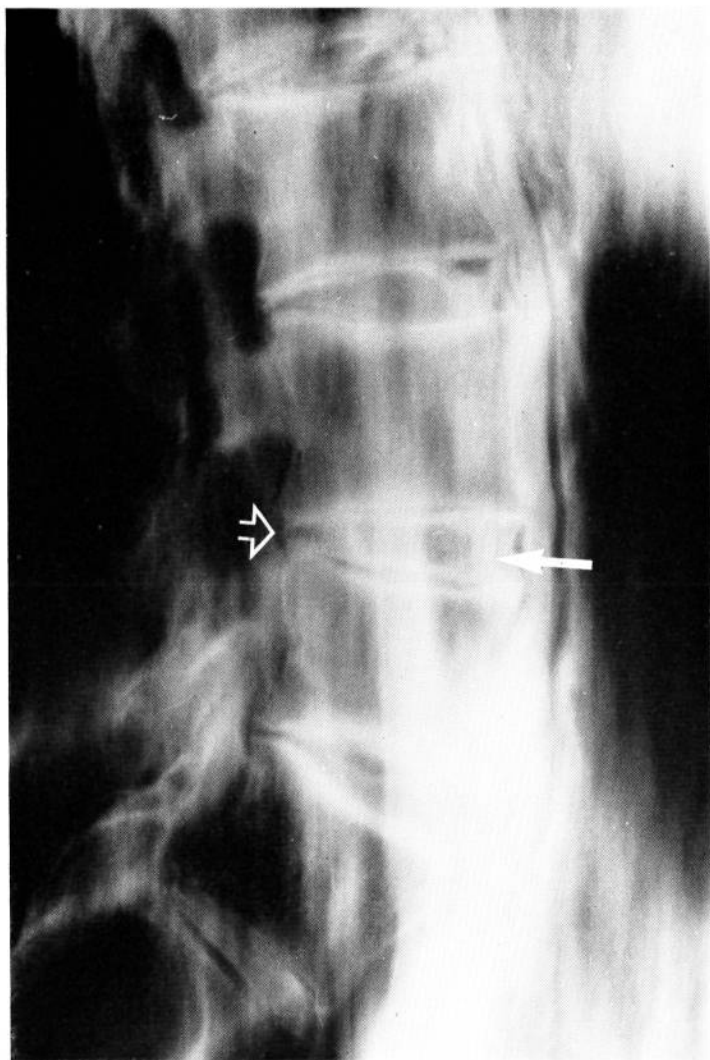
(9) 9354 (Khary). Skull. Biparietal thinning. Note calcification of falx.



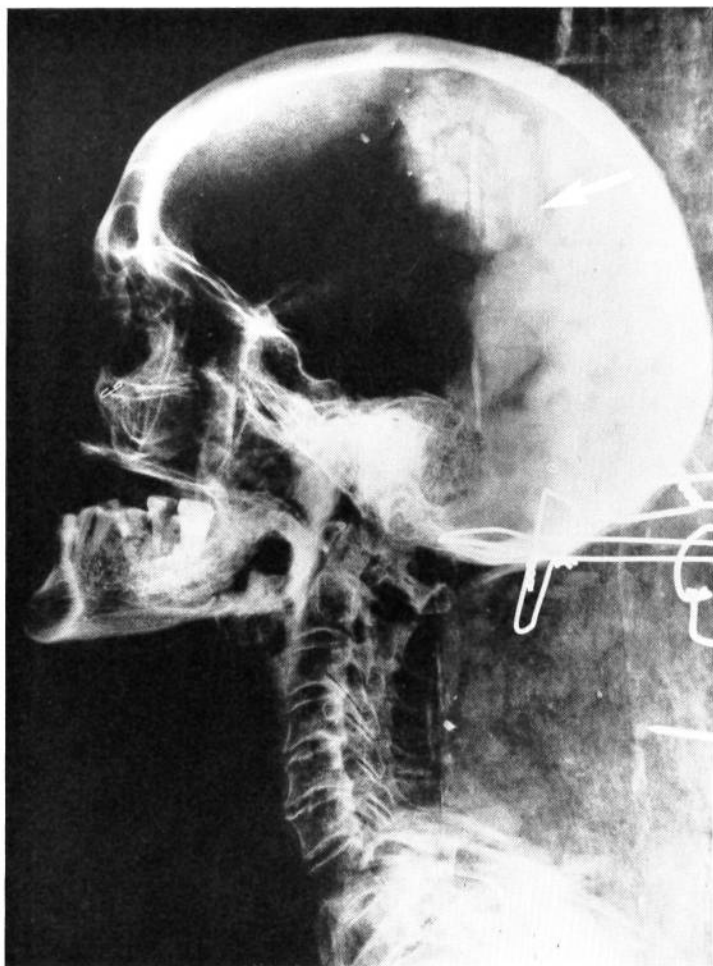
(10) 9354 (Khary). Chest. (*Left*) AP. Arms crossed, left hand clenched. Small cortical cyst on lateral aspect of right humerus (straight arrow). Note diaphragm (curved arrow).

(*Above*) AP tomography. Pericardium (straight arrow), heart (curved arrow) and right lung (open arrow) demonstrated. This area otherwise obscured by crossed arms.

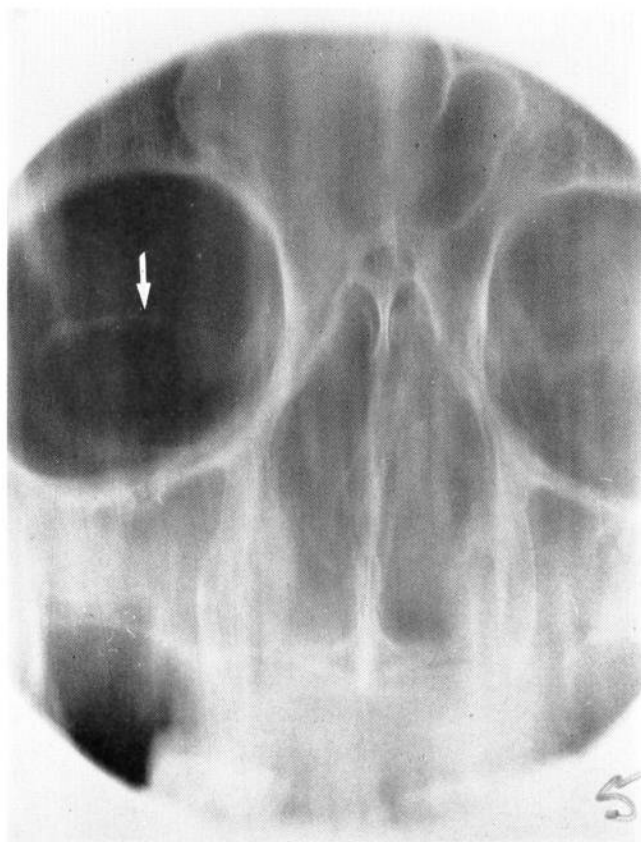




(11) 9354. Lumbar spine  
 (Above) Lateral tomography.  
 (Below) AP tomography.  
 Peripheral annulus of intervertebral  
 discs calcified (straight arrow),  
 nucleus spared (curved arrow).  
 Note protrusion of annulus at L3/4  
 (open arrow).

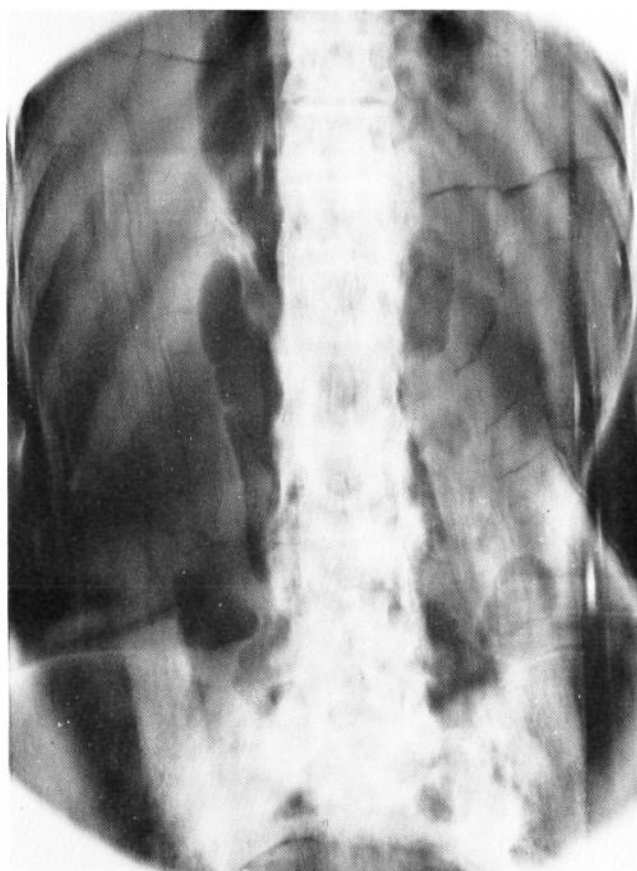


(12) 1976.51. Lateral skull and cervical spine. Residual brain material (arrow). Degenerative change and osteoarthritis in cervical spine. Note attrition of teeth.



(13) 1976.51. AP tomography face. Right frontal sinus and maxillary antra opaque. Ring opacity in right orbit (arrow) ? prosthetic globe.





(14) 1976.51

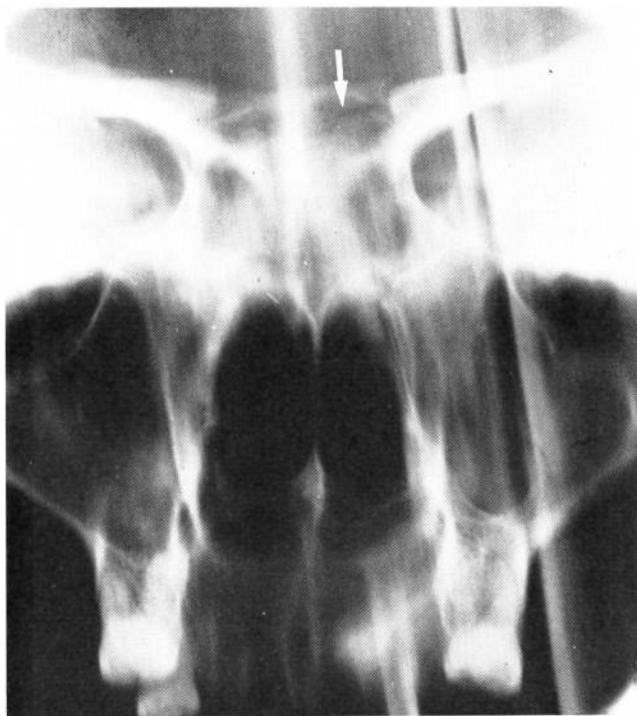
(Above) AP abdomen.

(Right) Ap tomography abdomen.

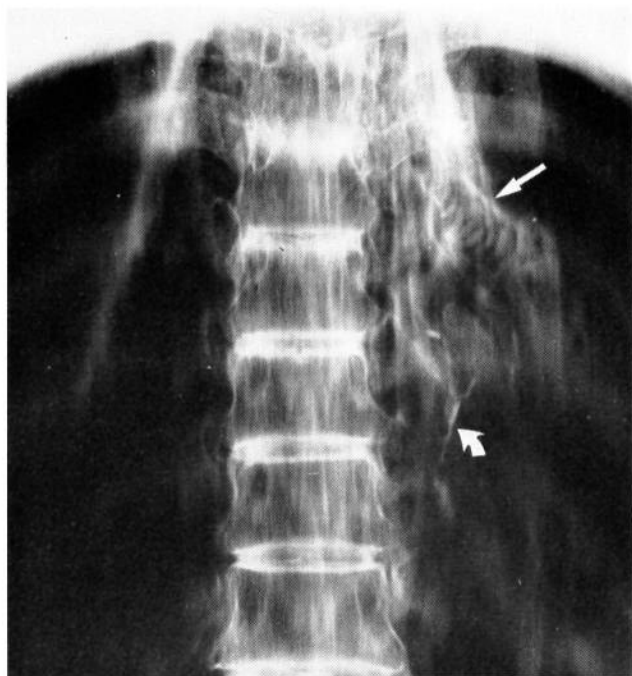
Air-filled tubular structure in mid-line. Note opacification of lumbar intervertebral discs and lateral osteophyte formation.



(15) 10881 (Ta-Aath). AP abdomen. Axial and appendicular skeleton jumbled.



(16) 10881 (Ta-Aath). AP tomography skull. Fracture of tuberculum sellae (arrow) due to brain removal.



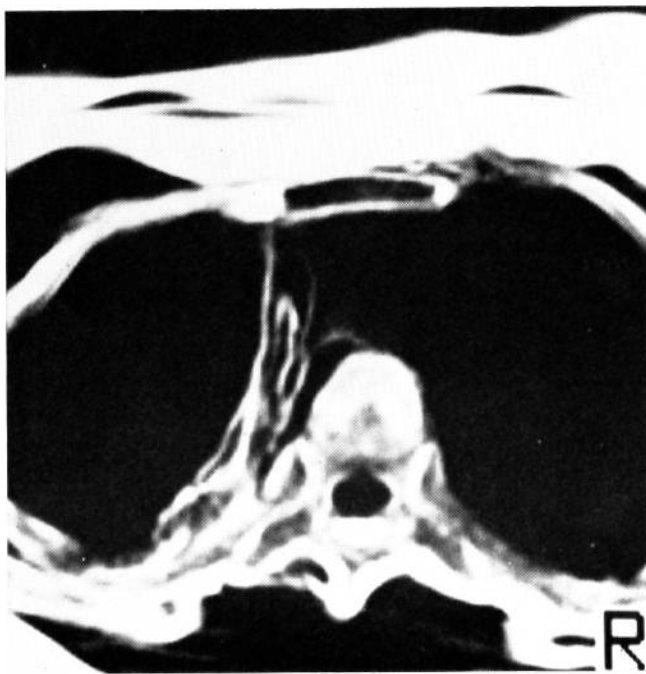
(17) 1777 (Asru). Upper thorax and skull.

(Left) AP.

(Above) Ap tomography.

(Below) Computed tomography.

Opaque cartilaginous rings of trachea and bronchi (straight arrow) and aortic arch calcification (curved arrow). Note lytic lesion in right parietal bone (open arrow) and intervertebral disc calcification.

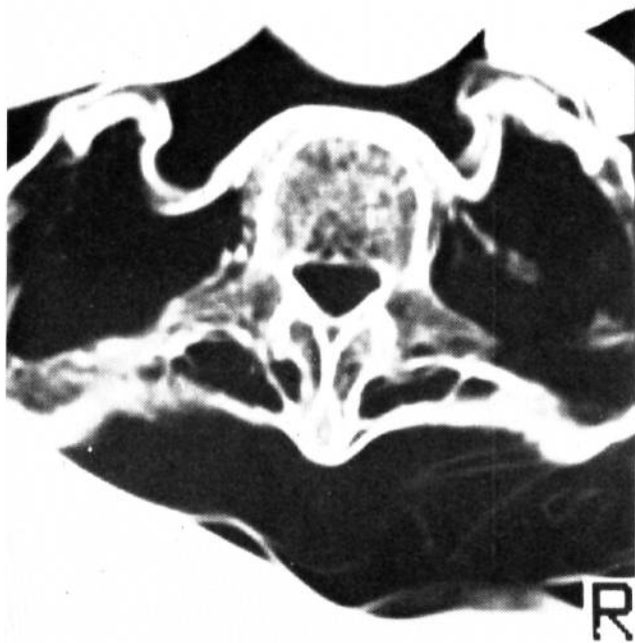




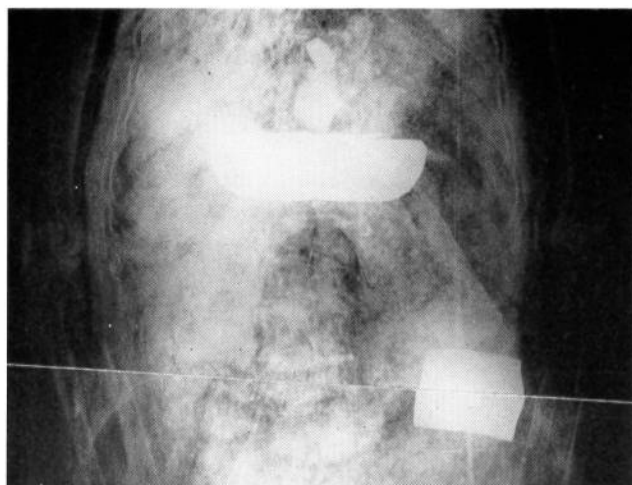
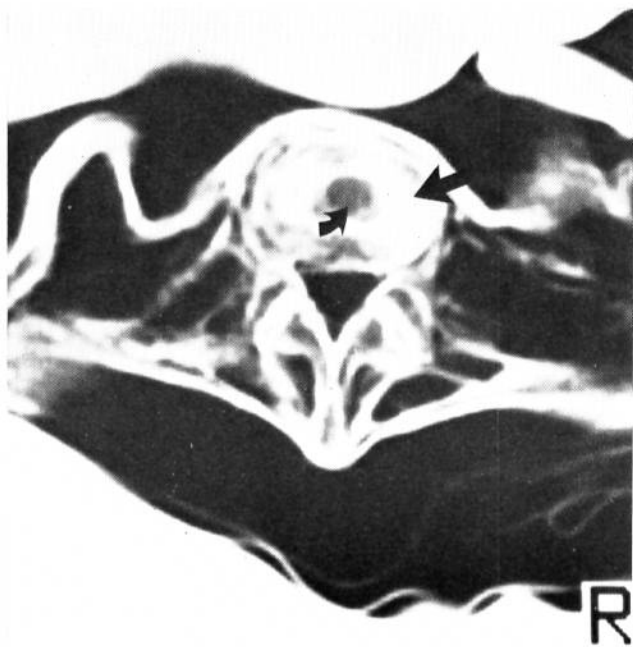
(18) 1777 (Asru). Lumbar spine.  
 (Above) Lateral.  
 (Below) Lateral tomography.  
 Partial collapse of L3 anteriorly due to old trauma (straight arrow). Extensive intervertebral disc calcification with herniation of L3/4 disc posteriorly (curved arrow).



(19) 1777 (Asru). AP hands. Osteoarthritis distal interphalangeal joints. Ankylosis of third proximal interphalangeal joint probably following infection (straight arrow). Note arterial calcification (curved arrow).



(20) 1777 (Asru). CT spine.  
 (Above) Mid-vertebral body.  
 (Below) Intervertebral disc level.  
 Calcification in intervertebral disc confined to annulus fibrosis (straight arrow). Nucleus spared (curved arrow).

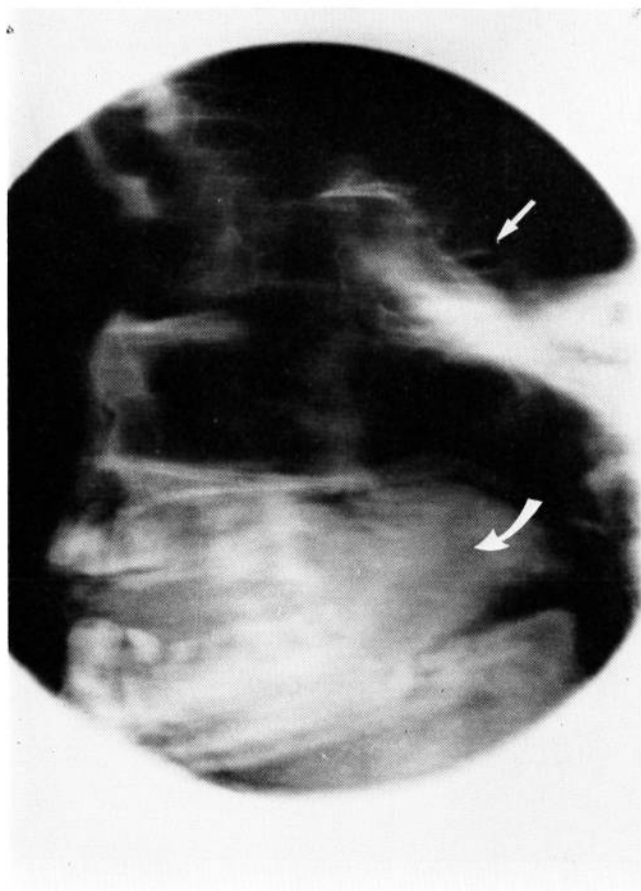


(21) 5053 (Per-en-bast). AP abdomen and thorax. Metallis Horus over mid-thorax and incision plate over left lower abdomen. Less dense scarabs above Horus.

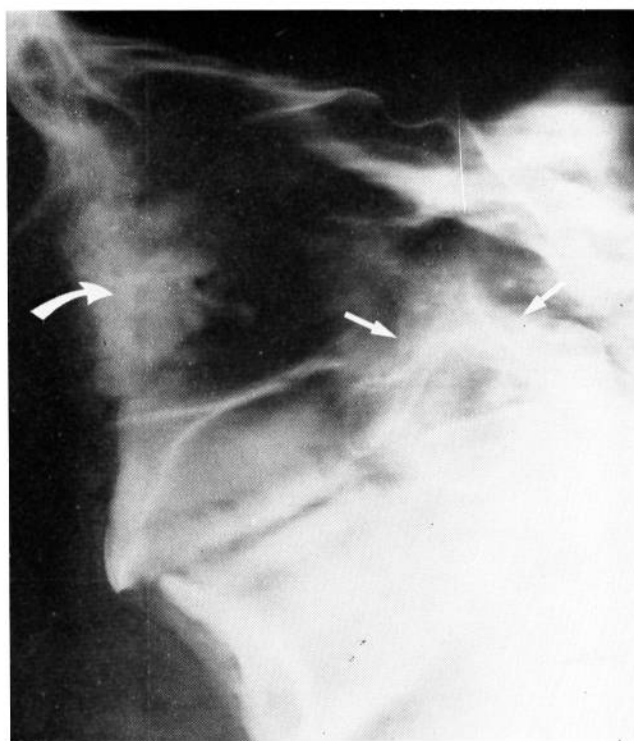


(22) 5053 (Per-en-bast). AP tomography lumbar spine. Partial collapse of L1 vertebra due to osteoporosis with osteophyte formation. Intervertebral disc material calcified.

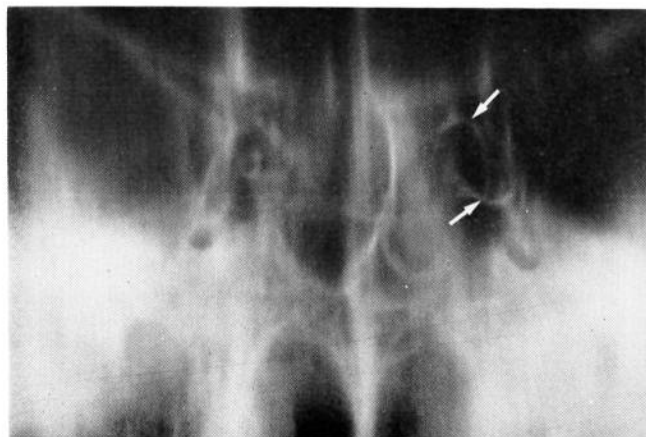




(23) 5053 (Per-en-bast).  
Tomography face and base of skull.  
(Above) Lateral.  
(Below) AP.  
Bilateral carotid calcification  
(straight arrow). Pack in  
oropharynx (curved arrow).



(24) 1768. Lateral tomography face and base of skull. Mid-cervical vertebral body in oropharynx (straight arrow); pack in anterior nares (curved arrow).

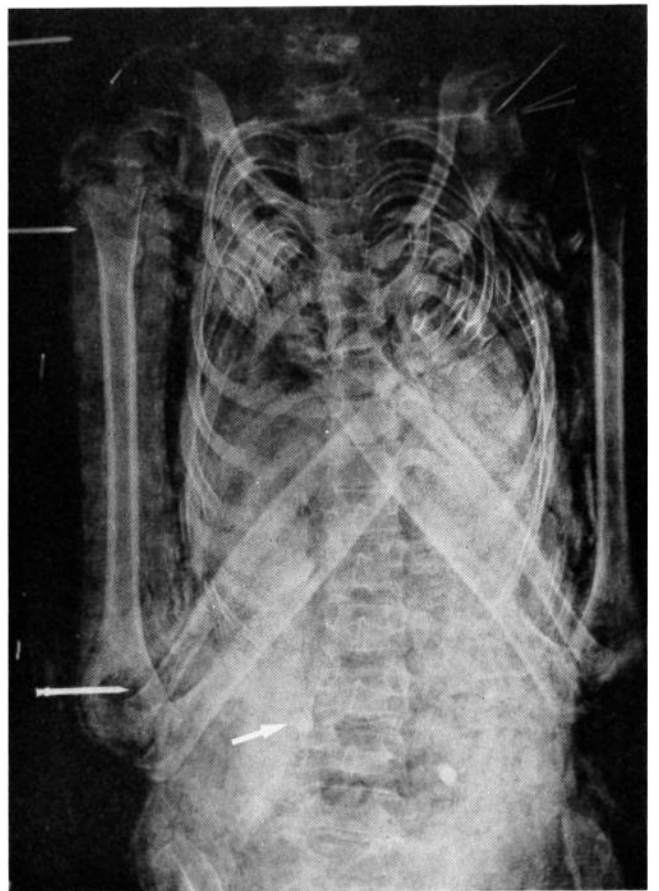


(25) 1768. Lateral knee. Osteoarthritis. Note calcification in meniscus (arrow).



(26) 1770. Lateral radiograph of cartonnage. Skull collapsed within.

(27) 1770. AP thorax. Pre-unwrapping. Arms crossed. Note discrete densities in abdominal wall, especially on mummy's right (arrow).





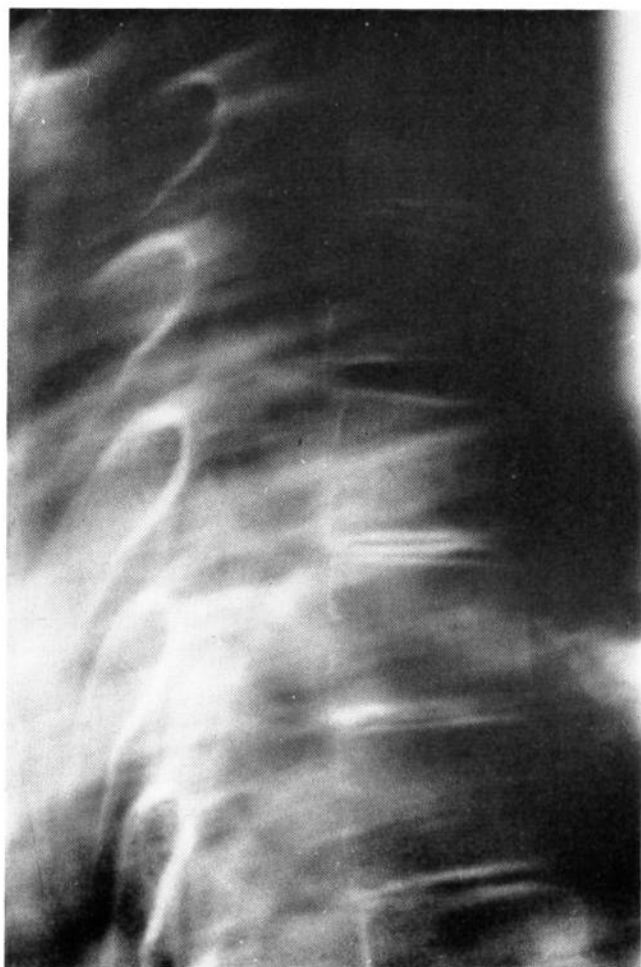
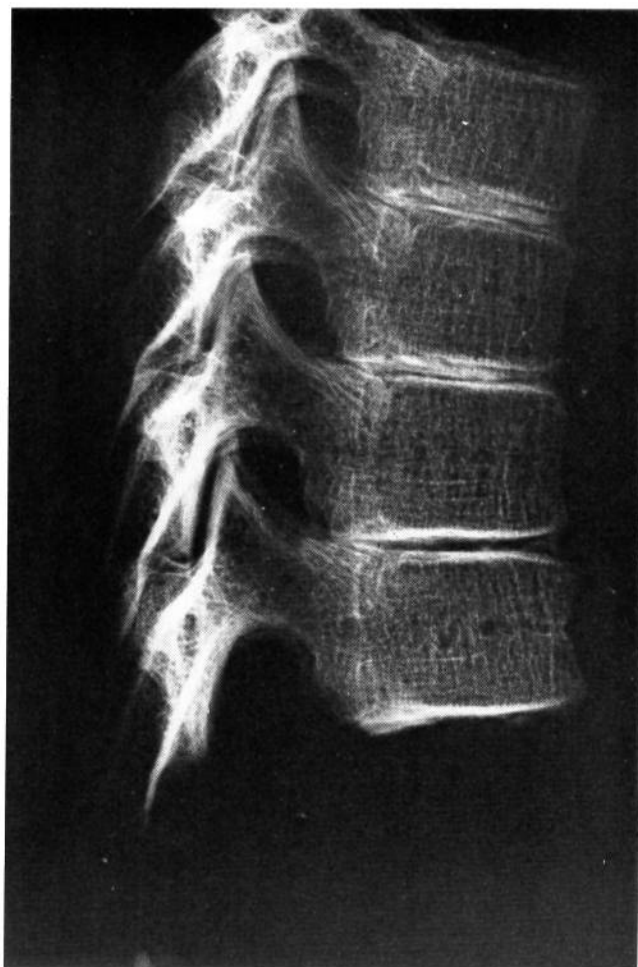
(28) 1770. Lower legs.

(Above) AP.

(Right) Lateral.

Amputations affecting both legs with prosthetic limbs added including feet. Epiphyseal development of a 14-year-old. Note displaced tooth.





(29) 1770. Lateral spine.  
 (Left) Pre-unwrapping.  
 (Above) Post unwrapping.  
 Calcification in discs due to resin.





(30) 1770. Macroradiography of abdominal wall density. Serpiginous outline of guinea worm (arrow).



(31) 1770. AP tomography facial bones. Hypoplastic left maxillary antrum.

(32) 1770. Radiography of sandals. No opaque material. Pigment presumed vegetable rather than mineral.

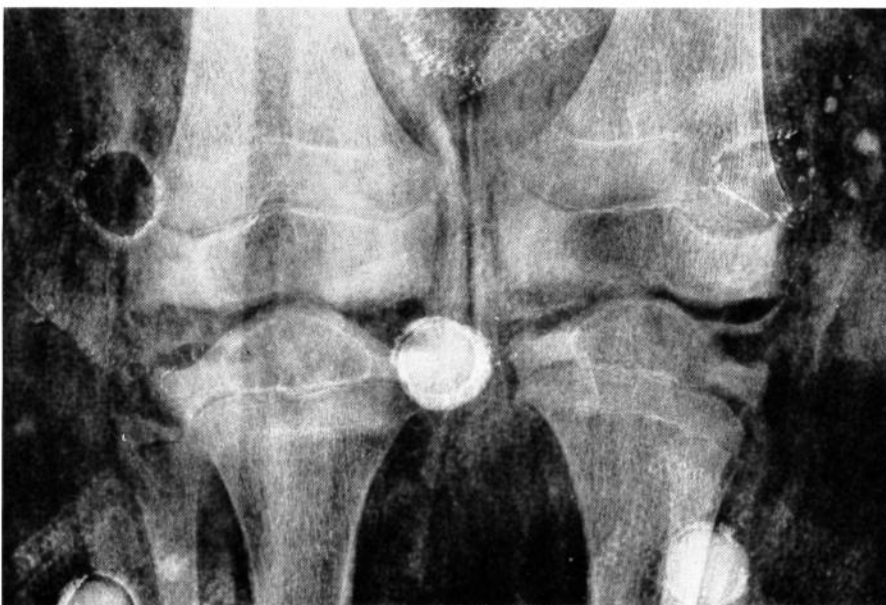




(33) 9319. Lateral tomography spine. Calcification of cartilaginous end plates in intervertebral disc spaces (arrow).



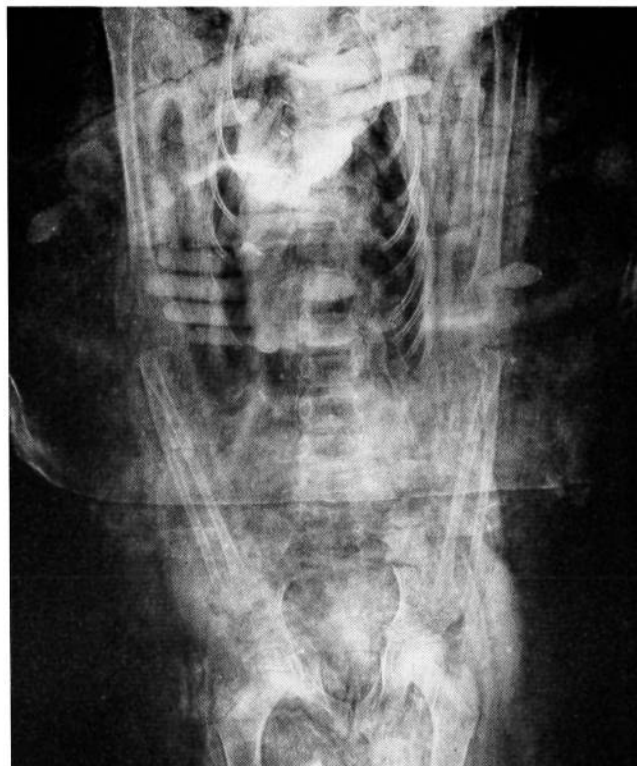
(34) 9319. AP left wrist. Capitate, hamate and distal radial epiphysis ossified. Bone age two years.



(35) 9319. AP knees. Lines of arrested growth in lower femora and upper tibiae. Calcification present in articular cartilage (arrow).



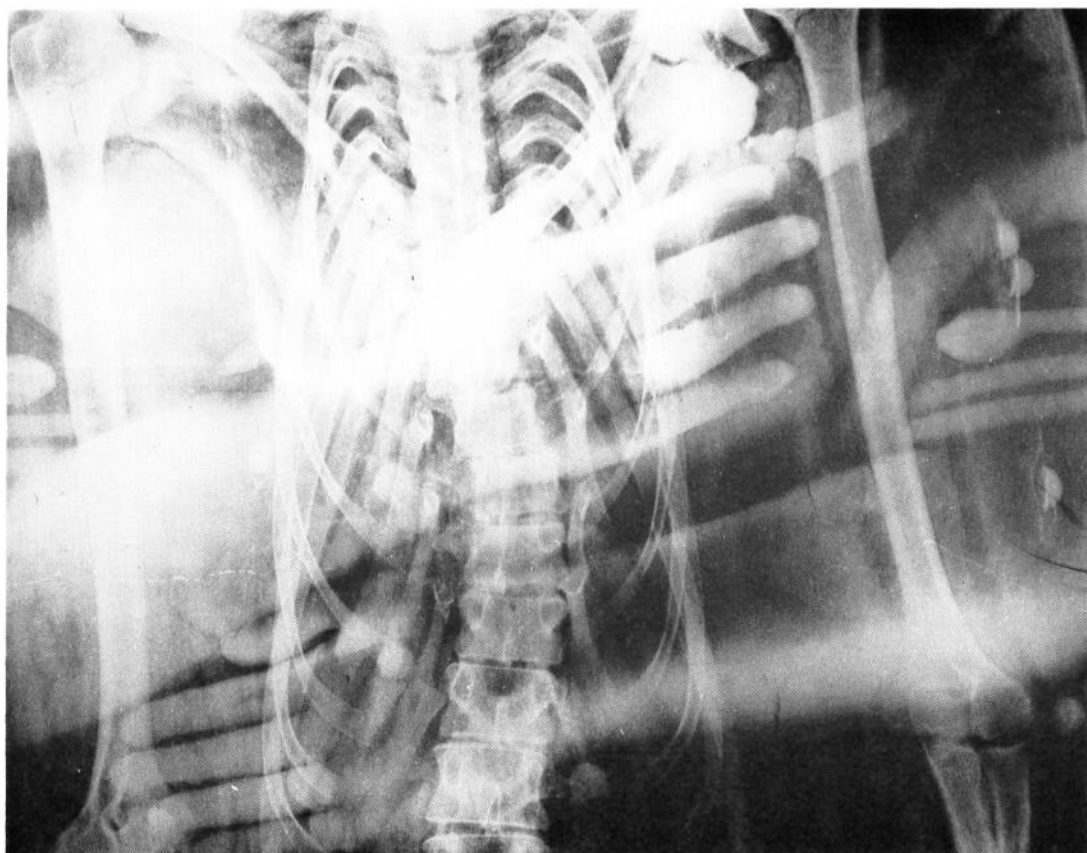
(36) 2109. AP thorax and abdomen. Skeleton disorganized with post-mortem fractures at T4/5 and T10/11. Note epiphyseal development of two-year-old.



(38) 1769. Abdomen.  
(Above) AP. (Below) AP tomography. Note package in right hemithorax obscured by overlying cartonnage.



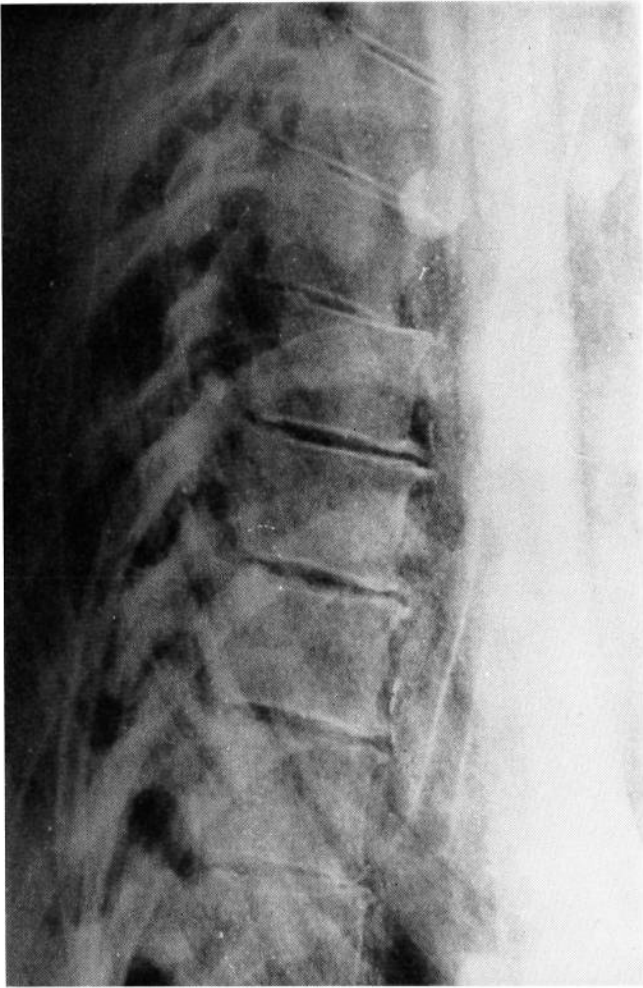
(37) (Left) 1769. AP skull. Skull position unrelated to cartonnage.



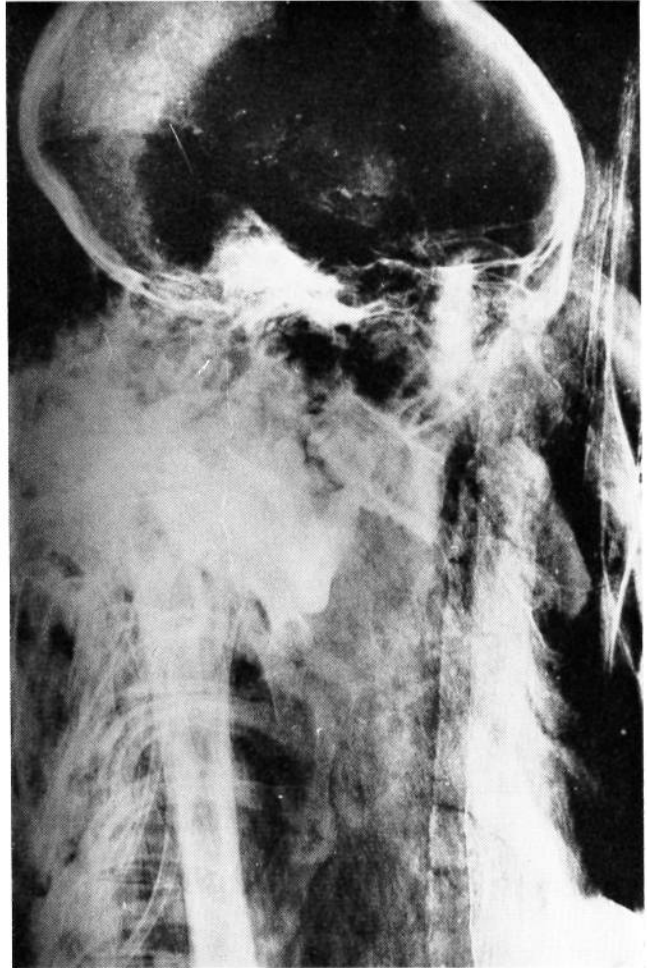
(39) 20638. (Demetria).  
 (Above) Thorax.  
 (Below) Abdomen.  
 Scoliosis convex to right in lumbar spine.







(40) 20638. Lateral thoracic spine. Post-mortem dislocation at T7/8. Anterior osteophytic lipping T8-12.



(41) 1767. Lateral skull, Facial bones. Mandible dislocated posteriorly.



(42) 1767. AP tomography upper and lower jaws. Left upper central incisor (straight arrow) reinserted by embalmer into right lower incisor socket (curved arrow).



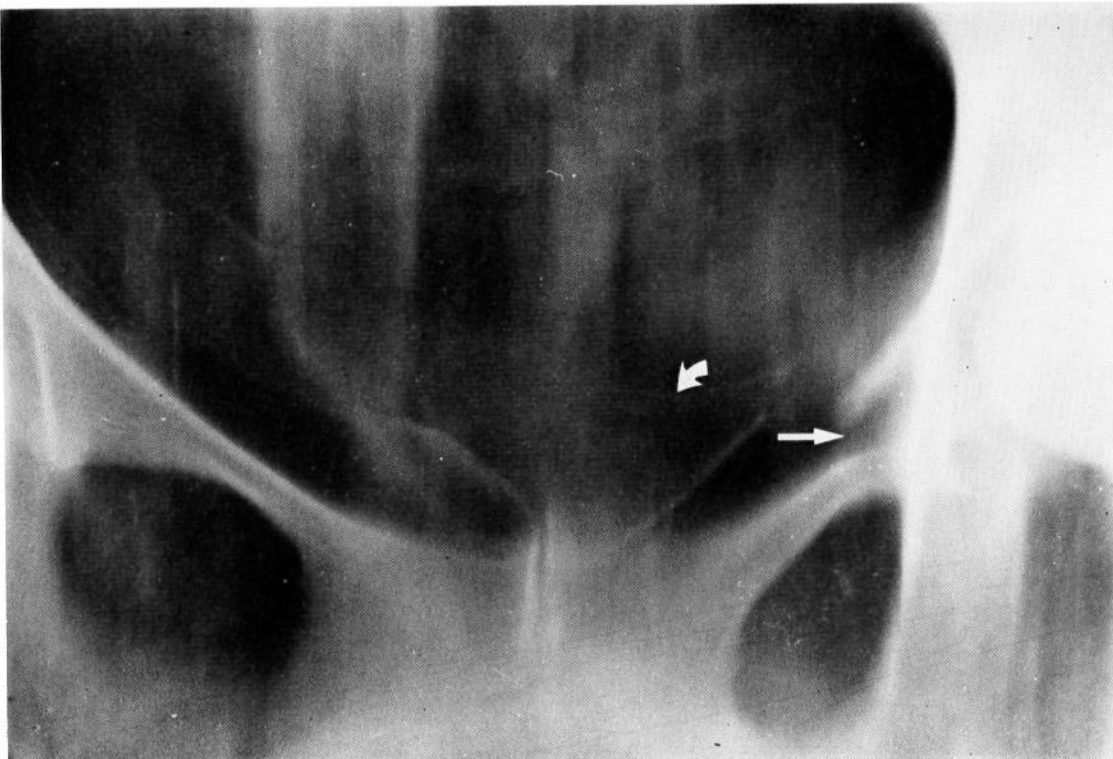
(43) 1767. AP pelvis. Arms extended and hands pronated over genitalia. Left hand over right.

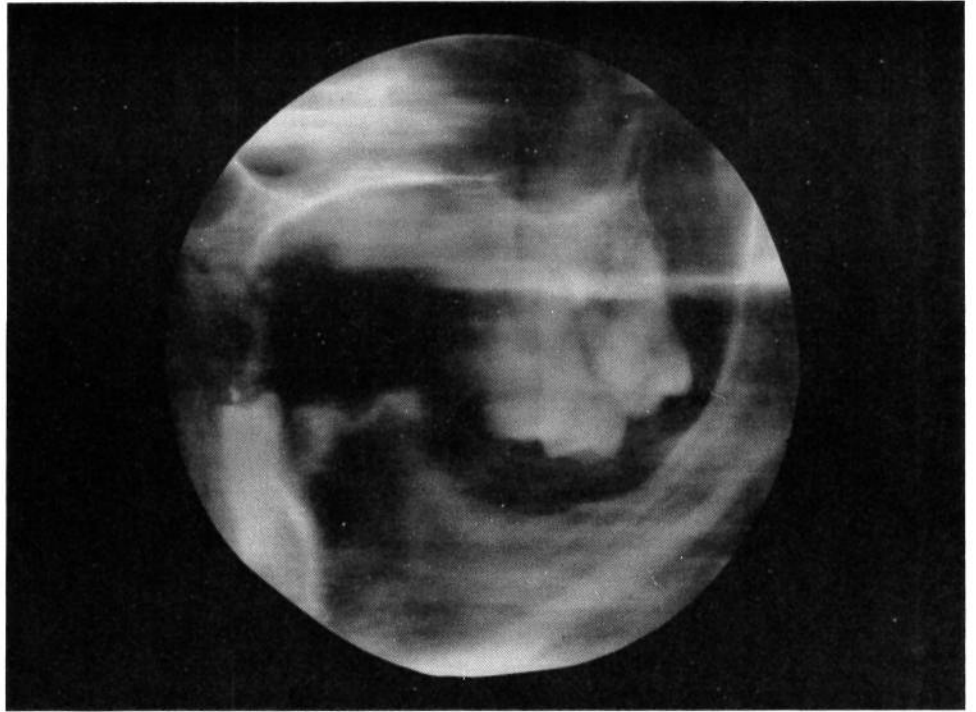


(44) 1766. AP skull. No bony abnormality. Jewelled eyes in cartonnage.

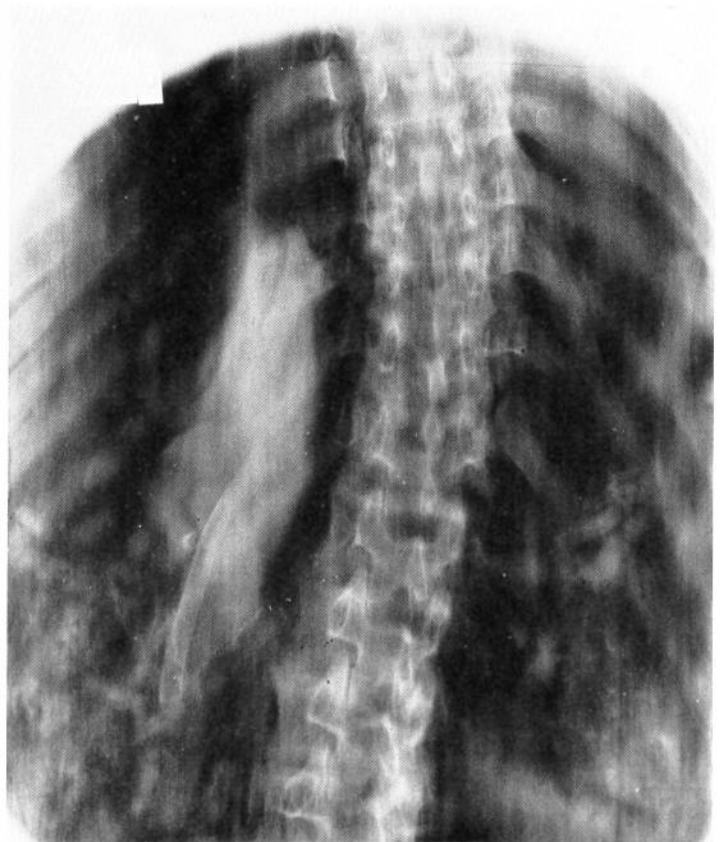


(45) 1766. Lower pelvis.  
 (Above) AP  
 (Below) AP tomography.  
 Ante-mortem fracture through left  
 superior and inferior pubic rami  
 (straight arrow). Calcification in  
 bladder (curved arrow) possibly  
 schistomiasis rather than tuberculosis



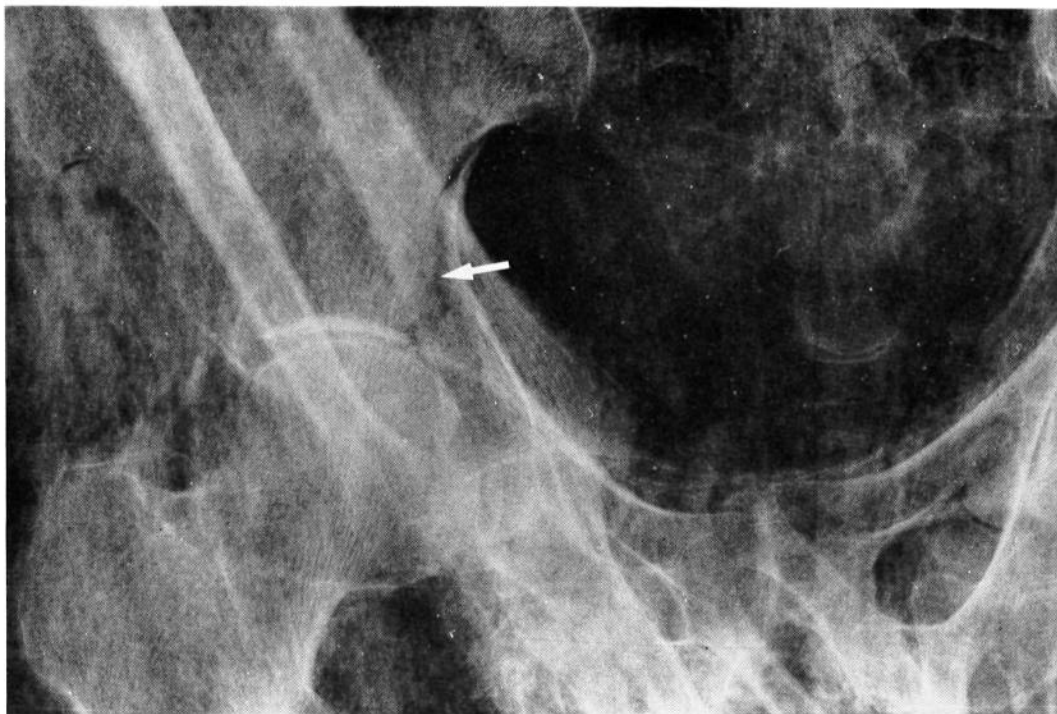


(46) 1775.  
 (Left) Lateral facial profile.  
 (Right) Lateral tomography.  
 Jaws demonstrate erosion of edentulous mandible by residual teeth.

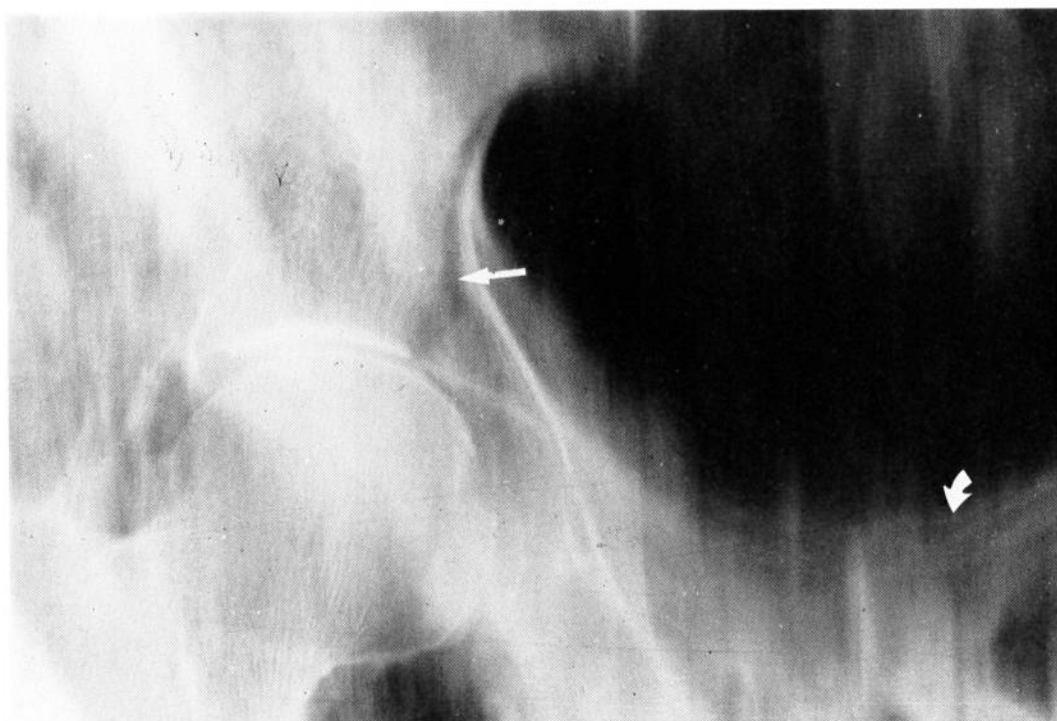


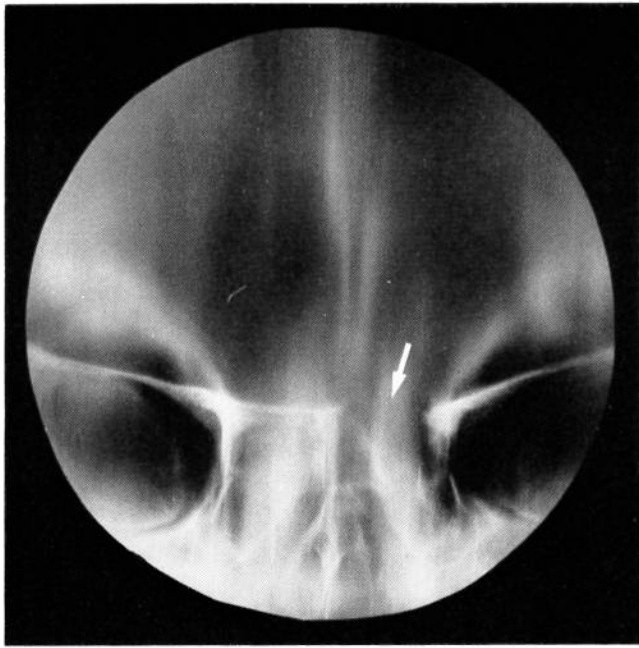
(47) 1775. AP thorax. Well-defined package in right hemithorax.



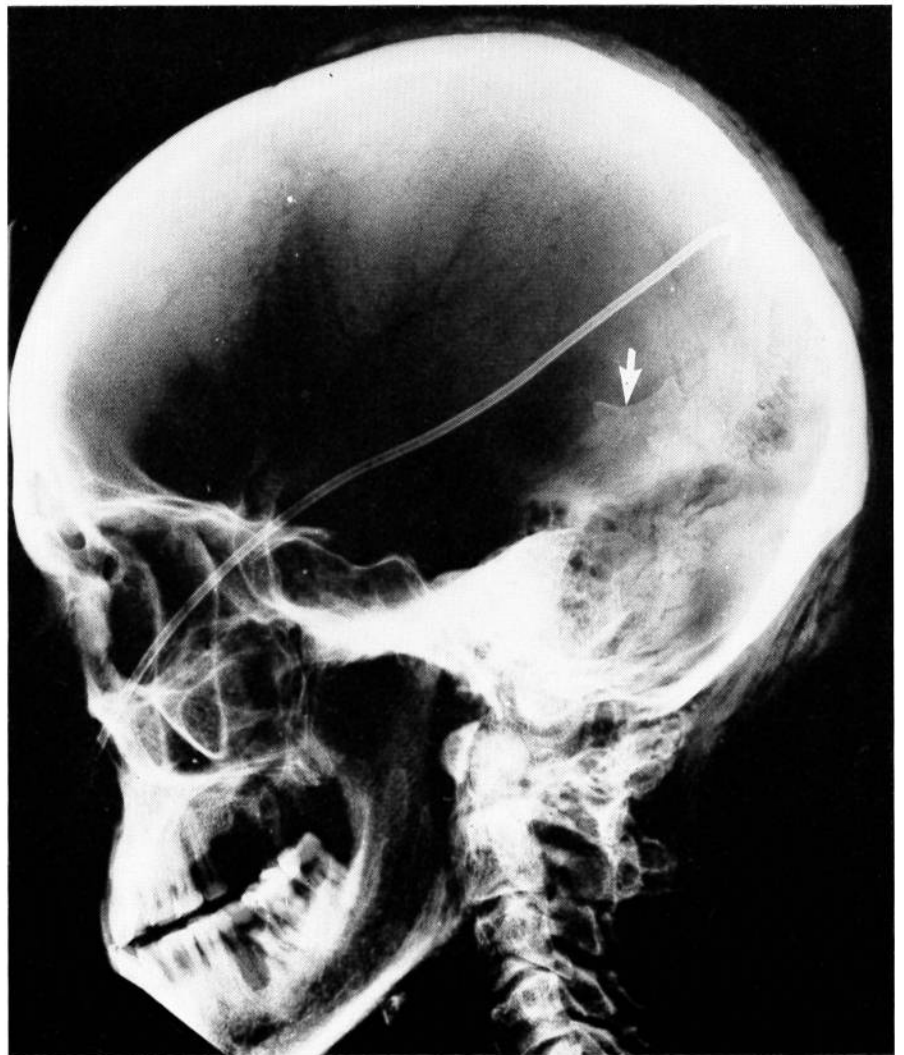


(48) 1775. Pelvis.  
 (Above) AP.  
 (Below) AP tomography.  
 Ante-mortem fracture through right  
 acetabulum into pelvic brim  
 (straight arrow). Calcification in  
 bladder (curved arrow). Probably  
 schistomiasis rather than  
 tuberculosis.





(49) 5275. Ptolemaic head. AP tomography. Defect in left ethmoidal roof produced by instrumentation for brain removal.



(50) 5275. Ptolemaic head. Lateral skull. Modern radio-opaque catheter inserted through nose into skull demonstrating route of brain removal. Note detached dorsum sellae (arrow).