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Case Study

Prostate metastatic bone cancer in an Egyptian Ptolemaic mummy, a proposed radiological diagnosis

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ABSTRACT

There is great interest in the history and occurrence of human cancer in antiquity and particularly in ancient Egyptian populations. Despite the number of Egyptian mummies and skeletons studied through various means, evidence of primary or metastatic cancer lesions is rare. The Digital Radiography and Multi Detector Computerized Tomography (MDCT) scans of a male Ptolemaic Egyptian mummy, from the Museu Nacional de Arqueologia (MNA) in Lisbon displayed several focal dense bone lesions located mainly on the spine, pelvis and proximal extremities. The exceptional detail of the MDCT images allowed the proposed diagnosis of osteoblastic metastatic disease, with the prostate being the main hypothesis of origin. These radiologic findings in a wrapped mummy, to the best of our knowledge, have never previously been documented, and could be one of the oldest evidence of this disease, as well as being the cause of death.

1. Introduction

The Lisbon Mummy Project (LMP) is a multidisciplinary project initiated in 2007 by a partnership between the Museu Nacional de Arqueologia of Lisbon and Imagens Médicas Integradas (IMI), a Lisbon private medical imaging group, and latter engaging the special support of Siemens Portugal.

The main purpose was the non-destructive evaluation of the three human and seven animal mummies from the Egyptian Collection of the MNA, for the very first time. None of the 10 mummies is provenanced, but the human mummies belonged originally to various aristocratic Portuguese families, at least one being traced to Lisbon in the second half of the 18th century (Araujo, 1993; Guedes, 1994).

In April 2007 the investigative phase began with the imaging of the animal mummies. These were radiographed and scanned at the main premises of IMI in Lisbon. High resolution imaging, showing great detail, was obtained for seven animal mummies: a pottery bird coffin, still sealed that contained the remains of part of an ibis, a wrapped falcon, a wrapped ibis, and four unwrapped crocodile mummies, one juvenile and three neonates. In August 2010 the LMP second phase was completed with the specially designed protocols for the study of the three human mummies of the collection: M1 – a wrapped Ptolemaic mummy (c. 285–30 BC); M2 – the Late Period male mummy named Pabasa (c. 523–332 BC) in an anthropomorphic wooden coffin; and M3 – a Third Intermediate Period male mummy of Irtieru (c. 945–712 BC), in a cartonnage mummy case.

2. Materials and methods

In phase 2 the LMP examined the three human mummies from the MNA Egyptian Collection by digital X-rays and MDCT scans from Siemens. The former technique used a digital overtable (Iconos), with digital radiography (DR) in an extended vertebral view/long leg protocol) and computed radiography (CR), segmental anatomic views, with Kodak imaging plates, KV 60–80; automatic exposure), and the scans used a MultiDetector CT, Somatom Sensation (64 rows, Z-sharp technology and an isotropic resolution of 0.33 mm).

Specially designed protocols were used with 120 kV, mAs ranges between 450 and 700, a tube rotation of 1.5 s, and the smallest pitch, of 0.45.

These values were applied selectively to different body ranges, first with two overall upper and lower body global acquisitions with a larger field of view, and subsequent several shorter ranges for special anatomic areas, selectively adapting the parameters to the expected absorptions at each segment and the intended final detail.

The large volume of radiological data was analysed through advanced 2D and 3D processing modes at the state-of-the-art workstation lent by Siemens, in conjunction with the Osirix Imaging Software, on Apple Mac OS X.

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Fig. 1. M1, the Ptolemaic wrapped human mummy from the MNA Egyptian Collection.

The human mummies where evaluated following the protocol used on the Egyptian mummies collection of the National Museum of Antiquities of Leiden, Holland (Raven and Taconis, 2005). As such, all the data gathered was organized in five major sections: Physical Anthropology, Anatomic Embalming details, Degree of Preservation, Anomalies and Paleopathology, and Wrappings and Artefacts.

Similar work has been carried out on other Egyptian collections, but with different parameters and mainly achieving lower resolutions (Raven and Taconis, 2005; Hoffman et al., 2002; Chan et al., 2008).

Fig. 2. MDCT MPR (coronal oblique) of the pelvis, showing the section of the mummified penis and right ischiatic sclerotic spots.

The achieved 2D and 3D results where globally exceptional, with the latest providing beautiful images but, as expected, it was the 2D data through the multiplanar reconstruction (MPR) analysis that provided the more relevant diagnostic data.

3. Results

Although all the mummies studied were of varying degrees of interest, paleopathologically, the most interesting mummy was M1 (Fig. 1) (Cat. 215; Inv. E500), an unnamed wrapped Ptolemaic mummy (c. 285–30 BC), apparently produced in the standard manner, adorned with a cartonnage mask and bib, and an elaborately painted shroud (Araujo, 1993; Ikram and Dodson, 1998). Applying the skeletal physical anthropology criteria it belongs to a male, a view further justified by the preserved male perineal anatomy and an obvious mummified penis (Fig. 2). It showed a calculated aged between 51 and 60 years (based on tooth wear, epiphysial fusion, and bone density), and a calculated stature of 1.66 m, with a cranial index of 77.4.

The digital X-rays of the mummy showed that it had been positioned with crossed arms, a pose that was common in Ptolemaic mummies, although in the New Kingdom it was most closely associated with royal burials. The mummy had suffered from extensive fractures (Fig. 3) in the arms, vertebrae, ribs and shoulder girdle, part of the left iliac, femoral heads and the left lower tibia/fibula, all consistent with a post-mortem origin. This is probably due to a post-mummification rough handling as well as during the transport of the mummy to Europe.

Signs of lumbosacral osteoarthritis (L4/L5/S1) were found, probably related to a lower lumbar scoliosis, which is fairly common in Egyptian mummies.

Of much greater interest was an abnormal bone pattern of multiple focal medullary dense bone lesions, mainly identified through the high resolution MDCT scans and from multiplanar reconstruction (MPR) analysis. They were found on several vertebral bodies, mostly lumbar (Figs. 4–6) and are generally rounded, with sizes varying between 1–2 and 15 mm. They were found at T7 (one, slightly less dense lesion), T12 (two lesions), L2 (three lesions), L3 (five lesions), L4 (seven lesions), and L5 (two lesions). At the

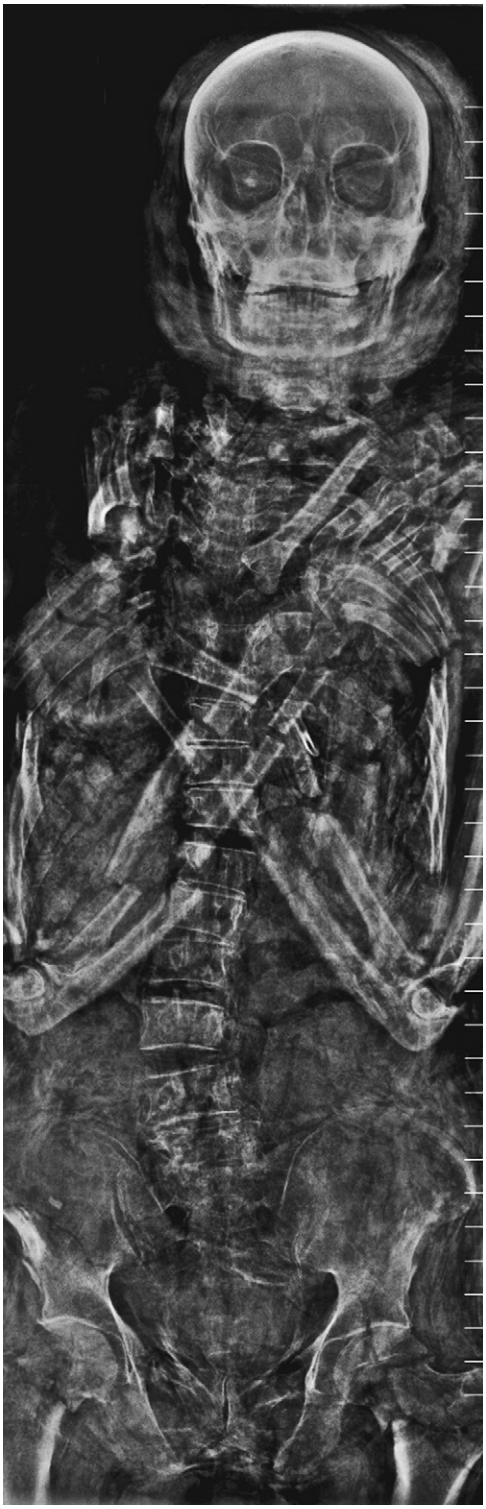

Fig. 3. X-ray digital extended-view of the upper body, showing the crossed arms mummification position and extensive post-mortem bone fractures.

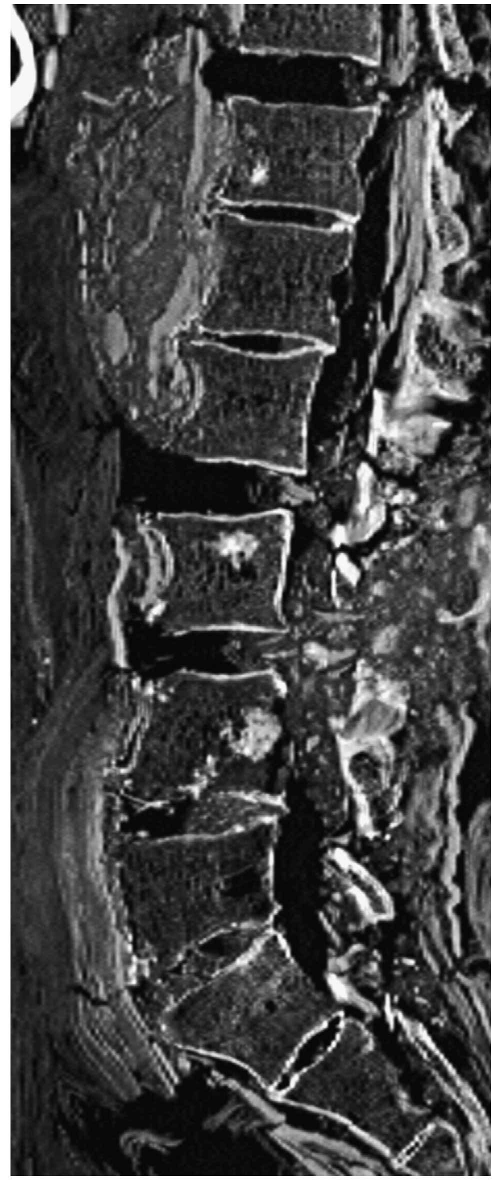

Fig. 4. MDCT MPR (sagittal) of the lumbar spine, showing sclerotic vertebral bone lesions.

pelvic skeleton both iliac wings showed similar dense areas (Fig. 7), slightly larger (right wing 2.8 cm, and left 2.3 cm), and with a more irregular pattern. The main lesion at the right iliac wing shows slight cortical thickening and focal erosion, with a lamellated adjacent reaction. The medullary areas of both clavicles, the left scapula, three ribs, both ischia (Fig. 2), and all humeral and femoral heads (Fig. 7) were punctuated by dense spots or small nodules, measuring between 1 and 4 mm.

Some other small, ill-defined and less dense, bone focal changes identified at other parts of the skeleton (frontal skull, mandible, and odontoid process), are not characteristic of any sole disease.

In the related analysis of the preserved pelvic soft tissue, we could identify the inferior bladder wall, the prostate fossa filled with debris and collapsed seminal vesicles embedded in resin accumulated in the rectovesical space (Fig. 8).

Some of the preserved muscles, particularly at the limbs, showed several small oval areas of low density, some of which have dense or calcified centers. It is unclear if these are due to taphonomic changes or a parasitic disease: trichinosis.

4. Discussion

Despite the large number of studied human remains, from antiquity to modern ages, evidence of primary or metastatic malignancy is rare but not unknown (Capasso, 2005; Pahl, 1986; Torre et al., 1980). Destructive (osteolytic) or bone forming (osteoblastic) ancient bone lesions are rarely identified. Even if this scarcity of bone cancer findings could be partially reduced by careful physical

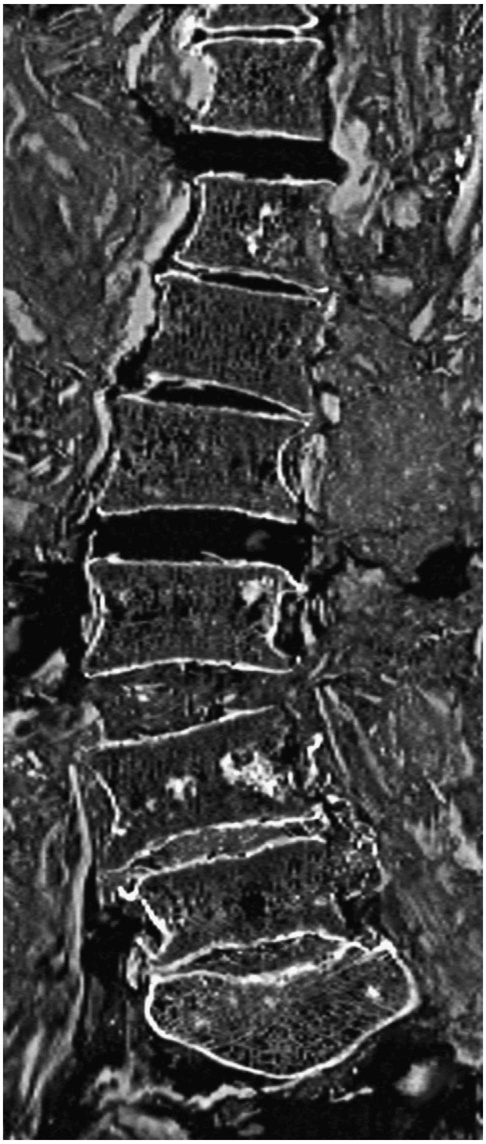

Fig. 5. MDCT MPR (coronal) of the lumbar spine, showing sclerotic vertebral bone lesions.

examination and by a more frequent use of non-destructive radiographic analysis, the main reason might be related to the much lower prevalence of carcinogens in ancient societies and shorter life span (David and Zimmerman, 2010).

The bone lesions found in the M1 Ptolemaic mummy were considered very suggestive of metastatic prostate cancer.

On the skeleton, metastatic prostate cancer usually shows itself as osteoblastic or bone forming lesions. Prostatic carcinoma has a typical bone spread with the most affected area being the pelvic region, the lower axial skeleton (particularly the lumbar spine), the proximal ends of the humeri and femurs, the ribs, and ultimately reaching most of the skeleton (Anderson et al., 1992; Batson, 1940; Cher, 2001; Yuh et al., 1996). However it is very rare for the distal extremities to be involved (Reigman and Stokkel, 2004). Although other tumors, such as lymphoma, carcinoid tumors, and mucinous adenocarcinoma of the gastrointestinal tract, to name but three, can cause similar lesions, they are rarer and have a different distribution pattern (Rodallec et al., 2008).

At the pelvic soft tissue images, the prostate fossa limits seem well preserved, but the absence of disruption of the prostatic fossa in cancer does not argue against prostate cancer, due to their

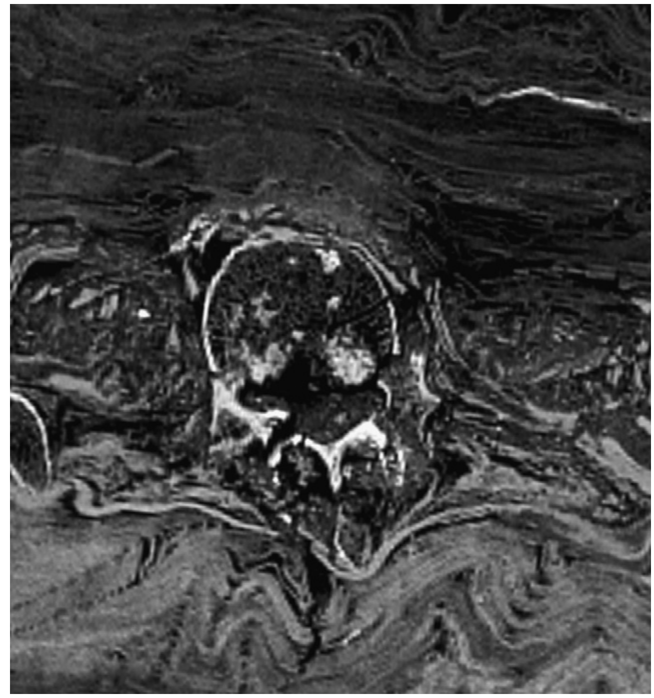

Fig. 6. MDCT MPR (axial) of L4, showing sclerotic bone lesions.

frequent small size and absence of extracapsular disease, even when linked to an advanced metastatic spread (Bubendorf et al., 2000).

However, other sources for such bone sclerotic lesions distributed thus must be considered. No known taphonomic factors (including insects, fungi and bacteria) or bone trauma (callus formations due to fractures) could possibly account for these lesions. The radiological patterns found in bone infarcts, melorheostosis, tuberculosis, osteomielytis, and degenerative bone diseases are not in keeping with the findings in M1 (Resnick, 2002). Two remaining options are enostosis (bone islands) and osteopoikilosis. However, in the case of the former, the lesions are fewer, smaller, denser, better defined and randomly located (Onilsuka, 1977). M1's lesions are not homogeneous, have irregular contours, and most are larger and less dense. In the case of the latter, a very rare sclerosing dysplasia of bone, the lesions are in great number and spread throughout the skeleton, being also better defined and denser (Harmston, 1956).

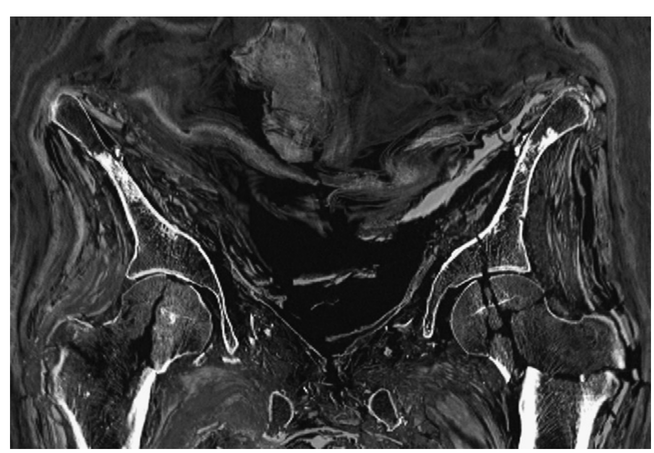

Fig. 7. MDCT MPR (coronal oblique) of the pelvis, showing sclerotic bone lesions of both iliac wings, and in the right femural head.

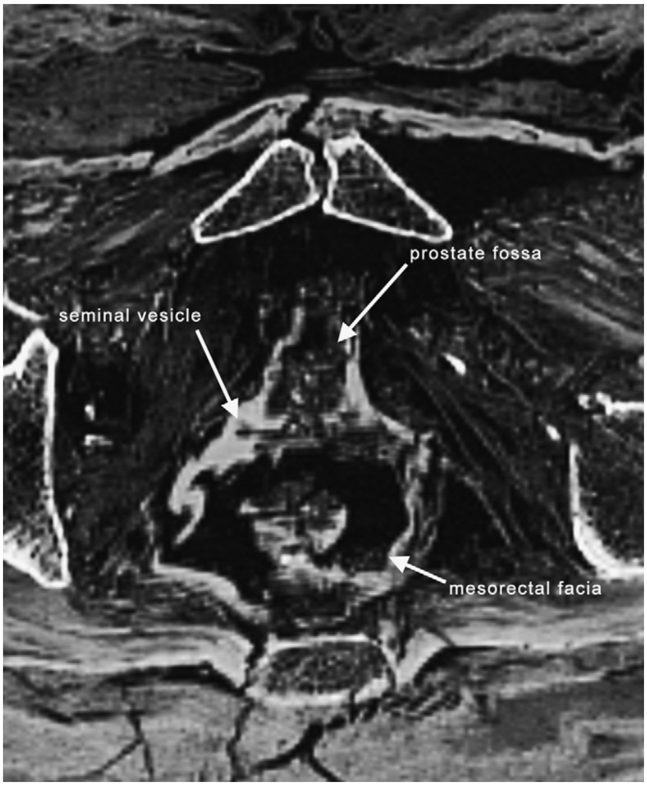

Fig. 8. MDCT MPR (axial oblique) of the pelvis, depicting the preserved perineal anatomy (annotated).

Thus, the most probable diagnostic for the bone lesions would be a metastatic osteoblastic disease. M1's sex, age, and the distribution of the lesions all argue for prostate cancer, particularly since this is the most common form of diagnosed male cancer, at least, today (Logothetis and Lin, 2005).

Assuming that diagnosis, the extension and pattern of the bone spread is more frequently related with less differentiated histologically tumours (more aggressive), and an higher frequency of extraosseous spread (Yamashita et al., 1993), it is thus acceptable to include the proposed diagnosis as an admissible cause of death of M1.

Several scholars have demonstrated that it is possible to apply contemporary diagnostic techniques to identify cancers in ancient remains, and examples of various forms of cancer, although rare, have been noted in ancient Egyptian remains (Nerlich et al., 2006; Strouhal and Nemeckova, 2004; Strouhal and Jungwirth, 1977; Strouhal, 1978; Strohual and Vyhnanek, 1981; Weiss, 2000; Zink et al., 1999). Indeed, prostate cancer has been described in at least three papers, but with direct evaluation of skeletal remains, not in a wrapped mummy, and none from Egypt or of an equivalent ancient date (Anderson et al., 1992; Baraybar and Shimada, 1993; Tkocz and Bierring, 1984).

Prostate cancer has no known cause, but has several identified modern risk factors: age, race and previous family history. In this case study from ancient Egypt age is obviously the only risk factor that is well supported, since familial and racial distribution factors are not accessible. Modern cultural factors, such as diet (animal fat intake or Vitamin D deficiency), are also being researched as contributing factors to prostate cancer, but cannot really be transposed to M1 due to an absence of a personal narrative. The main etiologic lines of investigation are centered on genetic and phenotypic alterations that are potentially involved in prostate carcinogenesis (Lin et al., 2011; Ruitjer et al., 1999).

It is possible that in the future this proposed diagnosis might be confirmed by palaeohistological analysis, or immunologically, using bones and tissue that have come loose and are now stored in the museum vault (Aufderheide, 2004; David and Zimmerman, 2010; Lin et al., 2011; Reding et al., 2001; Schultz et al., 2007; Weiss, 2000; Zimmerman, 1981).

5. Conclusion

Although cancer seems to have been rare in ancient populations due to a variety of reasons, including a shorter life expectancy and the absence of many carcinogens encountered subsequent to the Industrial Revolution, this investigation of a Ptolemaic Egyptian mummy strongly suggests that prostate cancer, the most common type of modern cancers, was present in antiquity. These radiologic findings in a wrapped mummy, to the best of our knowledge, have never previously been documented, and could be one of the oldest evidence of this disease, and also constitute an admissible cause of death.

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