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An overview of the evidence for tuberculosis from ancient Egypt

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Abstract

The diagnosis of tuberculosis in ancient Egyptian human remains has been largely based on spinal degeneration, or Pott's disease. Since the late 1990's, developments in biomolecular techniques have made possible the retrieval of ancient Mycobacterium complex DNA from ancient bones and tissue, as well as the ability to identify the specific strain of Mycobacterium causing the disease. This paper presents an overview of the evidence for tuberculosis in ancient Egyptian skeletons and mummies from the early 1900's to the present.

Introduction

This paper presents an overview of the study of tuberculosis in ancient Egypt, and how the ability to recognise and diagnose tuberculosis from ancient human remains has changed over time. In particular, since DNA was first retrieved from an ancient Egyptian mummy in 1985 (Pääbo, 1985), tremendous progress has been made in not only recognising *Mycobacterium tuberculosis* (TB) DNA in ancient Egyptian human remains, but also particular strains of *Mycobacterium*, and how they may be related, and may have evolved during the time span of ancient Egyptian civilization.

Traditionally, of course, bones are what have been studied for evidence of past disease, and in the case of *Mycobacterium tuberculosis* that means identifying bone lesions. Approximately 4% of the people infected by M*ycobacterium tuberculosis*, in the modern world, develop bone lesions as the bacteria spreads from the lungs in the blood and lymph system into the bone marrow (Brown and Brown, 2011, p. 711). This means that 'only a few cases with bone tuberculosis may indicate a much more widespread epidemiological occurrence of the disease' (Zink et al., 2001, p.355). A diagnosis of tuberculosis is almost always based on lesions in the thoracic and lumbar vertebrae (Brown and Brown, 2011, pp.849-850). In their most destructive form these lesions cause vertebral collapse and fusion, producing the curved spine known as Pott's disease, named after Sir Percival Pott who was a surgeon at St. Bartholomew's Hospital in London, and first described it in 1779.

Physical diagnosis

The first published description of Pott's disease in ancient Egyptian and Nubian remains was by Derry in his 1909 anatomical report in the Archaeological Survey of

Nubia. In the first case in his report he describes the spinal disease in the skeleton of a young woman from a C-Group cemetery near Bab al-Kalabsha. A short note is also added in by G.E. Smith describing the extremely bent spine and psoas abscess of the mummy of the 21st Dynasty High Priest of Amun Nesperehan from Thebes, which Smith and Ruffer published the following year (Derry, 1909, pp.31-32). Nesperehan's case of Pott's disease is probably the most famous from ancient Egypt (Ruffer, 1921, pp.3-10).

Morse, Brothwell, and Ucko summarised the evidence for tuberculosis in ancient Egypt and Nubia in 1964, presenting the evidence from literature, art and skeletal remains. This is still probably the most quoted article on the subject. They state that the cases based on skeletal remains were all identified on 'the basis of involvement of the spine; bone tuberculosis in other locations would be indistinguishable from too many other diseases' (Morse, Brothwell, and Ucko, 1964, p. 528). In all, they give the evidence for 31 cases. In 1988, Strouhal reported on two newly found burials with vertebral tuberculosis, and briefly reviewed all of the evidence for it from Egypt and Nubia again (Strouhal, 1991). He also produced a further update in 1999, including the earliest results of work with *Mycobacterium tuberculosis* DNA (Strouhal, 1999), which will be discussed below.

The evidence used for a tuberculosis diagnosis expanded first in 1979, when Zimmerman published microscopic confirmation of pulmonary TB in the partially preserved post New Kingdom mummy of a child from an intrusive burial at on the West Bank of Thebes. He found 'tubercle bacilli in the vertebral bone' and red blood cells in the trachea and lungs that was 'consistent with fresh and probably fatal hemorrhage' (Zimmerman, 1979, pp.606-607).

Genetic diagnosis

The next development came in the 1990s when work with ancient DNA began to recover DNA from viruses, bacteria and parasites. In 1997 Nerlich and Zink announced the retrieval of a DNA sequence from the lung tissue of a New Kingdom Egyptian mummy of a 35-year old man from the West Bank of Thebes that showed 'homology to the DNA of *M. tuberculosis*'. This molecular evidence backed up a macroscopic examination, which had shown evidence of pulmonary tuberculosis with osseous spread (Nerlich, et al. 1997). A more detailed publication of this study came out in 1999 (Zink et al., 1999)

In 1998 a team, working with Crubezy at Adaima in Upper Egypt, was able to retrieve a DNA fragment from samples of the rib and vertebra of a Predynastic Period child with Pott's disease that was 'sequenced and is consistent with an original *Mycobacterium* sequence' (Crubézy et al., 1998). Subsequent work with this DNA suggests that it was an ancestral or archaic form of *Mycobacterium tuberculosis*, which existed at the time when urban life emerged in Egypt beginning around 3400 BC (Crubézy et al., 2006). The example of the skeleton of another young child with multiple bone tuberculosis from the Predynastic cemetery of Adaima published in 2011 'provides a picture of a period where tuberculosis must have been endemic throughout the population during the origins of urban settlement' (Dabernat and Crubézy, 2011).

The biomolecular work of Zink and Nerlich and their team continued. DNA was extracted from bone and tissues samples from Early Dynastic period burials at Abydos, and burials from the West Bank of Thebes, dating from the Middle Kingdom to Second Intermediate Period, and from the New Kingdom to the Late Period. First thirty-seven skeletal tissue samples were tested (Zink et al., 2001), and then the number grew to eighty-three. Out of eighty-three samples, eighteen of them tested positive for *Mycobacterium tuberculosis* complex DNA. Six positive results came from individuals with macroscopic evidence of 'tuberculous spondylitis', five from individuals with 'non-specific pathological alterations', and seven from individuals with 'normally appearing vertebral bones' (Zink et al., 2003, pp.242-244). The team concluded that for about 2500 years the frequency of tubercular disease remained the same, and that 'this is the first evidence for an extensive presence of tuberculosis in various ancient Egyptian populations' (Zink et al., 2003, p.248). Two years later the team had analysed a total of one hundred and sixty bone and tissue samples, and thirty-eight of the samples, coming from all three of the different time periods, 'tested positive for the presence of mycobacterial DNA' (Zink, Köhler, and Motamedi, 2005, p.85).

These samples were further characterized by spoligotyping, and all showed a *Mycobacterium tuberculosis* or a probable *Mycobacterium africanum* signature (Zink et al., 2003, p.365; Zink et al., 2004, p.411). The Early Dynastic material produced evidence for an ancestral strain of *Mycobacterium tuberculosis*, while the Middle Kingdom samples were characterized by *Mycobacterium africanum* strains. The samples from the New Kingdom to the Late Period revealed 'a modern strain of *M. tuberculosis*, but not the ancestral strain seen in the Pre-to Early Dynastic period' (Zink et al., 2007, p. 388). No evidence for the strain of *Mycobacterium bovis* was found in any of these samples. It has generally been thought that *M. bovis* was ancestral to *M. tuberculosis*, and that tuberculosis passed to humans at the time they domesticated cattle, which would have been approximately 4500-5000 BC in Egypt (Roberts and Manchester, 2005, p.184; Nerlich and Lösch, 2009). A more recent hypothesis is that human *M. tuberculosis* is the most ancient strain, and ancestral to *M. bovis (Brosch, et al., 2002)*

Lipid signatures

One last development in the search to identify ancient tuberculosis is the technique to detect characteristic lipid components, or mycolic acids in the *Mycobacterium tuberculosis* cell wall. Mycolic acid can be extracted from a bacterial culture and examined by HPLC, or high performance liquid chromatography, which gives 'a characteristic trace that identifies the species of origin' (Brown and Brown, 2011, p.872). This technique was recently used in the re-examination of the Granville mummy, a Late Period older female named Irtyersenu from Thebes. This mummy had been first autopsied by Dr. Granville in 1825, who declared that ovarian cancer had been the cause of her death; recent studies state that this tumour was a benign cystadenoma (Donoghue et al., 2010, p.51). Since a histological study in 1994 noted a pulmonary exudate, samples from her lungs, gall bladder and membranous tissues were tested for *Mycobacterium tuberculosis* DNA, and samples from her femurs and lung were tested by HPLC for mycolic acids of

would appear that an active tuberculosis infection was the cause of Irtyersenu's death (Donoghue, 2010).

Conclusions

Our understanding of the nature and extent of tubercular disease in ancient Egypt has changed dramatically in the last century. Based on both skeletal and DNA evidence from the Upper Egyptian site of Adaima, Crubezy has been able to demonstrate that tuberculosis was 'endemic' at the time of urban settlement in early Egypt. This conclusion has been expanded upon by Nerlich and Zink who have retrieved DNA from skeletal samples from both Abydos and Thebes dating to later Pharaonic periods. They have not only shown that tuberculosis was widespread in the ancient Egyptian population over a period of about 2, 500 years, but they have identified that different strains of Mycobacterium were present at different time periods. The latest development in the identification of tuberculosis in ancient human remains has been to detect mycolic acid in *Mycobacterium tuberculosis* cell walls. This makes the identification of tuberculosis possible, even if its DNA cannot be successfully retrieved.

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