Paleoradiology of Egyptian Mummies:
A CT Imaging Survey of Cancer in Ancient Remains

Jennifer Willoughby[1], Kathryn J. Hunt[2], Roselyn A. Campbell[3] & Casey Kirkpatrick[1]

[1]The University of Western Ontario [2]Durham University [3]Cotsen Institute of Archaeology, UCLA

Paleo-oncology: A Definition

/pā-lē-ə-än-ˈkä-lə-jē/ : Research pertaining to the global history of cancer and other neoplastic diseases using archaeological, historical, clinical, and biomolecular methods of analysis.

Cancer in Ancient Egypt

Evidence for cancer from ancient Egypt has derived mainly from skeletal remains and from ambiguous textual references to possible symptoms of cancer. The arid climate of Egypt has allowed for exceptional preservation of both skeletal and mummified human remains. As a result, Egyptian archaeology provides a rare opportunity to investigate the history of disease, through the analysis of skeletal and soft tissue elements.

Although evidence for certain cancers can be readily apparent in some skeletal remains, the analysis of mummified soft tissues has the potential to contribute significantly to our understanding of cancer and other diseases in antiquity.

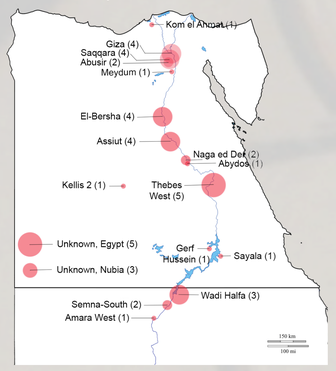
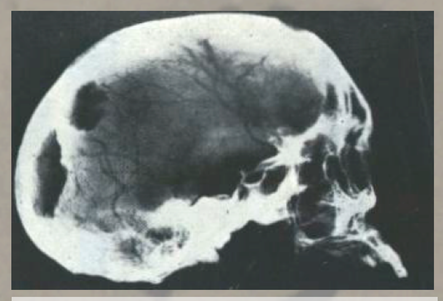


Figure A: Map of recorded evidence of cancer from ancient Egypt and Sudan (Hunt 2013)

Unfortunately, many studies of mummified remains have largely relied on destructive methods that may obscure possible pathological indicators and eliminate any hope of a complete re-analysis. Kathryn Hunt's 2013 meta-analysis, in collaboration with the Paleo-oncology Research Organization (PRO), found over forty published cases of cancer found in skeletal remains from all periods of Egyptian history and sixteen different sites (Figure A). Hunt's recent meta-analysis revealed that only 40% (93/230) of these published studies used radiological methods to determine a malignant diagnosis, and only 2/230 analyzed mummified tissue. Ancient Egyptian textual evidence for cancer is found mainly in the medical papyri, particularly the Edwin Smith Papyrus and Papyrus Ebers. Words referring to various types of swellings or inflammations (such as *aAt*) may indicate tumors such as neuroblastomas or Ewing's sarcoma (Hunt and Campbell 2014). Papyrus Ebers also refers to an "ill breast," a possible indication of breast cancer (Breasted 1930, Brothwell and Sandison 1967). While these written references are ambiguous, when combined with the physical evidence for cancer found in human remains, these strains of evidence indicate that cancer was present in ancient Egypt.

Paleoradiological Mummy Studies

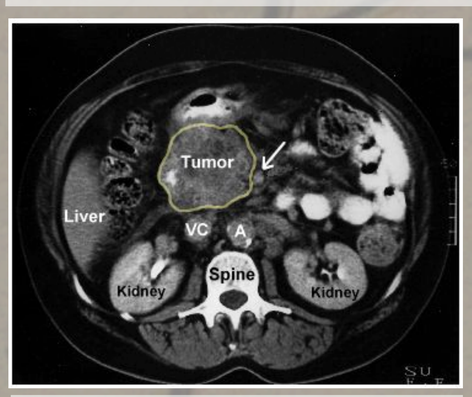
Shortly after x-rays were discovered in 1895, scholars recognized the potential for their application in archaeological examinations of mummified remains. Early researchers recognized the value of x-ray examination in estimating the age and sex of mummies, differentiating real and fake mummies, and recording information not visible to the naked eye (Böni et al. 2004). In addition to examining individual mummies, scholars used this new technology to document large numbers of mummies. The Field Museum in Chicago performed the first systematic radiographic analysis of a complete Egyptian mummy collection in 1931, and the Egyptian Museum in Cairo followed suit shortly after (Lynnerup 2010).



Radiograph of an archaeological skull showing destructive cancerous lesions

In the 1970's, computed tomography (CT) technology was developed, in which a machine takes x-rays along multiple planes while rotating around an object and then builds the x-rays into a 3D computer model of the object. Following Harwood-Nash's 1979 publication of the first case study using CT examination of an ancient Egyptian mummy, CT has become the 'gold standard' in mummy studies (Zweifel et al. 2009). CT is considered by many to be more suited to mummy studies than x-ray, as it is better able to differentiate tissues, while x-ray imaging superimposes soft tissues and is thus better suited for examining skeletal features. As imaging technologies continue to improve and become more affordable, x-ray and CT imaging are an increasingly accessible and practical method of analysis.

Identifying Disease in Ancient Egyptian Mummified Human Remains



Abdominal CT slice showing a soft tissue tumor. (Johns Hopkins University)

Recently, CT imaging has been used to identify a case of probable metastatic carcinoma in an ancient Egyptian mummy (Prates et al. 2011). CT examination of a Ptolemaic mummy of an older adult male presented multi-focal sclerotic bone lesions in the vertebrae, pelvis, scapulae, ribs and long bones. The authors found the most likely diagnosis to be metastatic carcinoma, likely secondary to prostate cancer. The use of CT in this case enabled the visualization of these lesions that would not be observable through other methods. The Prates et al. example of metastatic carcinoma was the first published case study of cancer in a mummy discovered through CT imaging, and demonstrates the applicability of CT methods for the imaging of cancers affecting bone. CT imaging also has the potential to visualize tumors in soft tissue preserved in mummified human remains.

The recent Horus Study demonstrates the usefulness of CT imaging in the identification of disease in soft tissues through their findings on cardiovascular disease in almost 40% of their 52 individual sample (Allam et al. 2011). These findings would have been undetectable in skeletonized human remains, demonstrating the importance of CT imaging in non-destructive analysis of mummified soft tissues. It is hope that the study presented in this poster will similarly contribute to our current knowledge of cancer in antiquity.

CT scan being performed on mummy for the IMPACT database. (Dr. Andrew Wade)

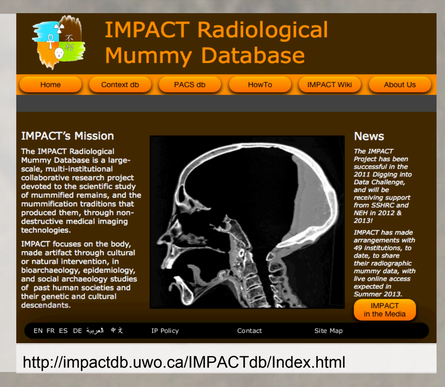
Presenting a New Method for the Study of Cancer in Antiquity

Until recently, research contributions to the field of paleo-oncology have predominantly consisted of individual case studies, with little focus on the broader impact of cancer on ancient populations. A recent meta-analysis, the first large-scale study of cancer in antiquity, has revealed over forty published cases of probable cancer in ancient Egypt, found mostly in skeletal human remains (Hunt 2013).

The current research project presented here is being conducted at the University of Western Ontario in collaboration with PRO. The project is a new large-scale survey of cancer in antiquity based on the analysis of computed tomography (CT) images of ancient Egyptian mummified human remains. CT imaging is ideal for the non-invasive analysis of naturally and anthropogenically mummified human remains, in which both bone and soft tissue are preserved, thus increasing the range of cancers that may be detected. Using the IMPACT Radiological Mummy Database, this project will contribute to our understanding of the applications of CT technology for the identification of cancer in mummies.

Research Materials: The IMPACT Database

The large collection of CT scans in the IMPACT database, hosted at the University of Western Ontario (Nelson and Wade 2013), provides a good base sample for a non-invasive survey of cancer in mummified human remains from ancient Egypt. The database consists of an image collection and a context database, which provides information on each individual mummy, including mummification style, origin, and date. The database currently holds data on approximately 100 ancient Egyptian human mummies, and will continue to expand to include mummies from around the world. This database provides a valuable toolbox for addressing epidemiological questions, and makes information on mummies located in institutions all over the world accessible to scholars.



http://impactdb.uwo.ca/IMPACTdb/Index.html

Research Materials: Data Collection

Data to be collected from CT scans of each specimen will include demographic, cultural, and pathological data. Demographic data, including age and sex estimation, will be recorded following standard anthropological methods (Buikstra and Ubelaker 1994), adapted for radiological examination. Cultural data will include qualitative descriptions of mummification style, as this affects which soft tissues will be present in the body as well as what materials have been added to the body. For the collection of qualitative and quantitative data on diseased tissues, a checklist for disease identification in mummies is being developed in consultation with radiologists and oncologists. Once all data has been collected, differential diagnosis will be performed to identify the disease processes affecting each mummy.

Research Materials: Differential Diagnosis

Abdominal CT scan of an ancient Egyptian mummy. (IMPACT database)

The process of differential diagnosis, *a compilation of all potential conditions in order of likelihood that could produce the observed symptoms* (Waldron 2009), differs greatly between clinical and bioarchaeological contexts. In clinical diagnosis, physicians observe a living patient in the context of their symptoms and medical history. For the purpose of treating the patient, they conduct radiological, histological and biochemical tests in order to confirm or revise a diagnosis. In archaeological material, there are no observable symptoms or medical history on which to base diagnosis, and in most cases, no soft tissues to observe. In the case of mummified human remains, some soft tissues remain, although they are dehydrated and very different in appearance from hydrated tissues. While limited by the lack of symptoms or patient history, bioarchaeologists have the advantage of being able to observe tissues directly to assess changes, and to use radiological examination without patient health concerns regarding radiation dosage.

The goal of diagnosis in archaeological specimens is to understand what disease processes affected the individual in life. The examination of diseases in the human past can contribute to current medical knowledge, and general understanding of human history, biology and culture. Bioarchaeological differential diagnosis is often based on changes to the bone or soft tissues that can be directly observed through visual examination, which can be supplemented with additional methods, including radiographic examination. Waldron suggests the use of operational definitions for diagnosis, based on standardized criteria that are comparable to other studies (Waldron 2009).

Conclusion

This ongoing paleoradiological research project will result in the development of radiographic tools for the documentation of cancer in mummified human remains, and operational definitions specific for the development of differential diagnoses of neoplastic disease based on radiographic observations. This research will advance paleo-oncological methods for the study of mummified human remains and will contribute to our understanding of the impact of cancer in the ancient world.

Bibliography

Allam AH, et al. (2011) Atherosclerosis in Ancient Egyptian Mummies: The Horus Study. Journal of the American College of Cardiology: Cardiovascular Imaging 4:315-327.
Aufderheide A, and Rodriguez-Martin C (1998) Neoplastic Conditions. In Aufderheide and Rodriguez-Martin (eds.): The Cambridge Encyclopedia of Human Paleopathology. Cambridge: Cambridge University Press, 371-392.
Binder, M. et al. (2014) On the Antiquity of Cancer: Evidence for Metastatic Carcinoma in a Young Man from Ancient Nubia (c. 1200BC). PLoS ONE 9(3): e90924.
Böni T, Rühli FJ, and Chhem R (2004) History of Paleoradiology: Early Published Literature: 1891-1921. JACR 55:203-210.
Breasted, J.H. (1930). The Edwin smith surgical papyrus (university of Chicago press, Chicago)
Brothwell, D. and Sandison, A.T. (1967). Disease in Antiquity. (Thomas, Springfield) p 512-513.
Buikstra JE and Ubelaker DH (1994) Standards for Data Collection from Human Skeletal Remains: Proceedings of a seminar at the Field Museum of Natural History (Arkansas Archaeology Research Series 44). Fayetteville: Fayetteville Arkansas Archaeological Survey.
Harwood-Nash D (1979) Computed Tomography of Ancient Egyptian Mummies. Journal of Computer Assisted Tomography 3:768-773.
Hunt K (2013) Cancer in Bioarchaeology: A Comprehensive Survey of Malignant Neoplastic Disease in Published Case Studies. Durham University: Unpublished MSc thesis
Hunt, Kathryn J., and Campbell RA. (2014). Cancer in Egypt: A Study of Literary and Bioarchaeological Evidence. Poster presented at the American Research Center in Egypt Annual Meeting.
Lynnerup N (2010) Medical Imaging of Mummies and Bog Bodies – A Mini-Review. *Gerontology* 56:441-448.
Nelson AJ and Wade AD (2013) IMPACT: Development of a Radiological Mummy Database. Anatomical Record. In Press.
Prates C, Sousa S, Oliveira C, and Ikram S (2011) Prostate Metastatic Bone Cancer in an Egyptian Ptolemaic Mummy, a Proposed Radiological Diagnosis. International Journal of Paleopathology 1:98-103.
Waldron T. (2009) Palaeopathology. Cambridge: Cambridge University Press.
Zweifel, L. Boni T, Ruhli F (2009) Evidence-based paleopathology: A meta-analysis of PubMed-listed scientific studies on ancient Egyptian Mummies. Homo - Journal of Comparative Human Biology 60(5): 405-427.

Use the QR code to get a pdf of this poster, and access other paleo-oncology content online. www.cancerantiquity.org

Acknowledgements

The authors would like to express their appreciation for the support of friends and advisors: Dr. Andrew Nelson, Dr. El Molto, Dr. Andrew Wade, Dr. Donald Ryan; colleagues at the Western Department of Anthropology the Paleo-oncology Research Organization, and to the Ontario Trillium Scholarship for funding this research