

Southern Illinois University Carbondale

OpenSIUC

Honors Theses

University Honors Program

8-2022

A Probable Case of Osteosarcoma: A Differential Diagnosis of Cancers in the Ancient World

Katherine A. Hosick
katherine.hosick@siu.edu

Follow this and additional works at: https://opensiuc.lib.siu.edu/uhp_theses

Recommended Citation

Hosick, Katherine A., "A Probable Case of Osteosarcoma: A Differential Diagnosis of Cancers in the Ancient World" (2022). *Honors Theses*. 479.
https://opensiuc.lib.siu.edu/uhp_theses/479

This Dissertation/Thesis is brought to you for free and open access by the University Honors Program at OpenSIUC. It has been accepted for inclusion in Honors Theses by an authorized administrator of OpenSIUC. For more information, please contact opensiuc@lib.siu.edu.

**A Probable Case of Osteosarcoma: A Differential Diagnosis of Cancers in the Ancient
World**

Katherine A. Hosick

A thesis submitted to the University Honors Program in partial fulfillment of the requirements
for the Honors Certificate with Thesis

Approved by Gretchen R. Dabbs, Ph. D.

Professor

College of Liberal Arts, Anthropology

Southern Illinois University Carbondale

August 23rd, 2021

Acknowledgments

I would like to thank my family, my friends, and my partner for supporting me during my undergraduate education. A special note of thanks to Dr. Elizabeth Donoghue, Dr. Jyotsna Kapur as well as to several others who supported me with words of encouragement and advice while I conducted this project. Thank you to the University Honors Program for giving me the opportunity to receive high quality education and pursue this research project.

Biographical Note

Katherine Hosick is an undergraduate student who is majoring in Anthropology and minoring in Forensic Science and American Sign Language at Southern Illinois University Carbondale (SIUC). At SIUC she has received the Dean's Scholarship, magna cum laude, and a few departmental scholarships in anthropology including High Honors in Anthropology and Outstanding Senior. She is a member of the University Honors Program, Phi Kappa Phi, and Saluki Service Dawgs. Katherine hopes to pursue a career in biological anthropology in the future.

Abstract

Ongoing archaeological investigations at the North Tombs Cemetery, Tell El-Amarna, Egypt, have, to date, yielded a skeletal sample of 141 graves and at least 252 individuals that have been recovered, representing the non-elite responsible for erecting, and inhabiting a new city (c. 1353 BCE) (Dabbs, 2020) . Recent data on the recovered remains show a trend toward pathological changes in the skeletons attributable to occupational stress-related injuries, specifically those associated with demanding physical labor. One individual (Individual 1154), who was buried wrapped in textile, as is typical of the cemetery exhibited an abnormal bony proliferative lesion on the fifth right metatarsal. The skeleton was in excellent condition, and other pathological lesions including spinal degenerative joint disease of the fourth thoracic vertebrae, thoracic vertebrae six through twelve, and the first lumbar vertebrae (as well as porotic lesions on the spine), non-spinal fractures of the proximal phalanx of a first-hand digit (side unknown) and of an intermediate hand phalanx of unknown position and side, and an abnormal bony abscess on the fifth right metatarsal. The irregular morphology in question is described, and a complete differential diagnosis is considered. The differential diagnosis rules out several other probable causes of the peculiar morphology of the fifth right metatarsal, including benign tumors such as osteochondroma, osteoma, osteblastoma, and malignant bone such as chondrosarcoma, Ewing's Sarcoma, and metastatic tumors. Given the location, morphology involving the surrounding bony changes leads the authors to conclude Individual 1154's fifth right metatarsal morphology is consistent with osteosarcoma.

Keywords

- Amarna, Egyptology, Osteosarcoma, Differential Diagnosis, Bioarchaeology

Objective: This project is designed to provide a differential diagnosis of a bony lesion from the Amarna site in Egypt.

Introduction

The archaeological representation of Akhetaten, the short-lived Egyptian capital city of Akhenaten (reign 1352-1336BCE), is Tell El-Amarna, Egypt. While best known as a settlement site, Amarna also preserves numerous large pit-grave cemeteries for the non-elite citizens of Akhetaten, which contains over 10,000 burials with most of the remains being wrapped in textile in a mat prior to burial (Stevens 2018). The investigation into Amarna cemeteries began in 2005 and has produced one of the most extensive well-excavated collections of burial remains from ancient Egypt. This offers researchers a unique insight into the health of ancient Egyptians, non-elite funerary practice in ancient Egypt, and life under Akhenaten. The North Tomb Cemetery of Amarna itself contains between 3,500–5,000 individuals (Stevens 2018). Evidence suggests that with the majority of the individuals excavated ranging in age between 7–25 years and evidence of having lived hard-working lives that these individuals were non-elite laborers (Dabbs 2020).

Ongoing archaeological investigations at the North Tombs Cemetery (one of four public non-elite burial grounds so far identified in the eastern bay of Amarna) have, to date, yielded a sample of 141 graves and at least 252 individuals, representing the non-elite laborers. Recent data on the sample show a trend toward pathological changes in the skeletons attributable to occupational stress-related injuries, specifically those associated with demanding physical labor (Stevens et al., 2018). One individual (Individual 1154) exhibited an abnormal bony proliferative lesion on the fifth right metatarsal.

Individual 1154 was found in a pit style grave in the North Tomb Cemetery. The individual was 12-13 years old based on dentition. Sex cannot be estimated for a subadult individual due to the lack secondary sex characteristic development in subadults. The individual, who has been given the identifier Individual 1154, was wrapped in matting/textile, as is consistent with other individuals within the cemetery (Dabbs, 2019), and the skeleton was in excellent condition. Pathological analysis showed non-spinal fractures of both a proximal phalanx of a first-hand digit (side unknown) and an intermediate hand phalanx, and an abnormal bony growth on the fifth metatarsal of the right foot (RMT5). The proximal digital phalanx exhibits a healing fracture of the base, resulting in a premature fusion of the proximal epiphysis base, which is crushed up into the diaphysis of the bone while the intermediate hand phalanx exhibits a healing fracture of the distal end, which has the appearance of a crush fracture resulting in a periosteal reaction present around the entire diaphysis along the distal end. The morphology of the R5MT shows an abnormal growth pattern showing mounds or folds of bone growth with a 'starburst' or 'sunburst' pattern and apparent porosity. Identifying specific lesion types in dry bone is not always possible. However, the location of the lesion and demographic profile of the individual affected, as well as changes in the morphology of the surrounding bone, offer helpful clues with identifying lesions that produce benign or malignant neoplastic bone (Buikstra 2019).

Performing a differential diagnosis is essential, regardless of the number of cases one is investigating, as studying the pathological conditions of one or many individuals can tell researchers how their lives may have been affected as well as can help researchers to better understand a particular site they are investigating. Publishing cases or examples of pathological conditions and differential diagnoses (even if only one case is discussed) allows further research into the

subject matter and allows future researchers to have an example that might be relevant to their cases. More importantly, the publishing of differential diagnosis cases provides information on geographic and temporal distribution of specific conditions. Small contributions to the paleopathology literature of individual examples, such as this one, allows for the broader understanding of the geographic patterning of similar lesions/conditions and allows for a greater understanding of the time depth associated with a condition.

Further, publishing and performing research on a pathological condition present in dry bone, such as cancer, is vital as tumors and tumor-like cysts arising primarily in the skeleton are uncommon as well as only a few cancers spread to the bone as the majority form in soft tissue which could further research on estimating cancer rates in ancient Egypt and the world more broadly (Ortner, 2003).

Material and methods

Basic skeletal data were collected for this individual in accordance with the standard procedures for osteological analysis (Buikstra and Ubelaker, 1994). Dental age was estimated using the London Dental Atlas (AlQahtani et al. 2010). The body was primarily (90%) complete, except for the lower legs, some epiphysis of the arm and lower leg, sternal ends, a right-side rib, phalanges of the foot, metatarsals, tarsals, hand phalanges, carpals, and metacarpal heads which make up the missing 10% of the skeleton.

A comparative approach was used for the differential diagnosis of the lesion observed on the individual's right fifth metatarsal. This approach can support an association between types of bone lesions and a potential cause or condition that affects this individual. This approach focused on bone tumors or lesions due to the morphology and proliferative nature of the lesion on Individual 1154's metatarsal, comparing both benign and malignant tumors to the visible

morphology of the metatarsal in question focusing on the least likely condition or tumor, first moving through each type, and moving towards the most probable cause of the morphology exhibited.

Description of Pathological Lesions and Conditions

Pathology showed a non-spinal fracture, spinal degenerative joint disease present in the thoracic vertebrae, trauma to a proximal firsthand phalanx as well as a fracture of an intermediate hand phalanx, and an abnormal bony lesion on the fifth right metatarsal. The skeletal lesion and anomaly reported in Individual 1154's right fifth metatarsal include mounds or folds of bone growth with a 'starburst' or 'sunburst' pattern and apparent porosity. The lesion involves the entire length of the diaphysis and lies on the superior-medial surface. Other pathological lesions and conditions appearing in the body indicate that most skeletal lesions observed can be attributed to probable nutritional deficiencies and acquired anemia, and some could have resulted from non-specific infection or inflammation or trauma.

The porosity of the spine includes thoracic vertebrae and the first lumbar vertebra. A fusion anomaly is shown on the right posterior neural arch on the first cervical vertebrae, where it should articulate superiorly with the occipital condyle. Thoracic vertebrae eight and nine exhibits subchondral bone destruction on the superior articular facets. A porotic lesion is also present on the anterior-medial surface of the femoral necks. The proximal phalanx of a firsthand digit (side unknown) exhibits a healing fracture of the base. An intermediate hand phalanx of unknown position and side exhibits a healing fracture of the distal end. Linear enamel hypoplasia and spinal degenerative joint disease are also present. With the exception of the proliferative lesion on the right fifth metatarsal, these lesions are all broadly consistent with the paleopathology of the broader North Tombs Cemetery skeletal sample (Dabbs, 2019).

Results

The skeletal lesion and anomaly reported in Individual 1154's right fifth metatarsal involve an abnormal shape and bone formation or morphology. The abnormality observed includes folds of bone growth with a 'sunburst' pattern and porosity. Bone cysts and benign and malignant tumors were all considered explanations for the pathological condition exhibited in the metatarsal. The most common primary malignant bone tumor is the osteosarcoma, followed by chondrosarcoma and Ewing's sarcoma in decreasing frequency, with all other types being rare (Ortner, 2003).

Conditions such as unicameral bone cyst, aneurysmal bone cyst, congenital epidermal inclusion cyst, traumatic epidermal inclusion cyst, enchondroma tumors, juxtacortical chondroma, hereditary multiple exostoses (diaphyseal aclasia), chondromatosis (Ollier's Disease), chondroblastoma, chondromyxoid fibroma, osteoma, osteoid osteoma, osteoblastoma, fibrous cortical defect, cartilaginous exostosis (osteochondroma), non-ossifying fibroma, cortical desmoid, giant cell tumor (osteoclastoma), hemangioma, meningioma, chondrosarcoma, and chordoma can be all ruled out as possible etiologies due to the elements affected, the morphology of characteristic lesions, the rarity of the condition, and the lack of diagnostic lesions linked to some of these conditions (Ortner, 2003) (See Table 1).

Chondrosarcomas were given special consideration as differentiating between them, and osteosarcomas may be dubious in dry bone; however, while the small tubular bones of the feet may frequently be the site of enchondromas, chondrosarcomas are infrequent in these bones, therefore have been excluded as a possible cause (See Table 1). Also, while reactive bone may make the distinction between Ewing's and osteosarcoma impossible in dry bone (Buikstra 2019), the morphology present on Individual 1154's metatarsal and the typical morphology described by

Ortner (2003), Ewing's Sarcoma has been eliminated as a possible cause based on the area affected being a long bone of an extremity or a pelvic bone and with the morphology typically consisting of loose round cells not held together by matrix compared to the morphology of the lesion on Individual 1154's metatarsal (Ortner, 2003). Chondromas were considered as they tend to affect those in the later stages of childhood and are often found in the small tubular bones of the hands and feet but was ultimately excluded due to its morphology where the tumor partially destroys the cancellous bone and, possibly, scalloping the inner cortex of long bones while, in the small bones of hands and feet, the outer contour may be altered, revealing a thin, new cortical shell, which may perforate and the tumor's center usually, and often heavily, calcified and sometimes ossified (Ortner, 2003). After researching the morphology and localization of other types of conditions, the possible pathological condition has been significantly narrowed down. The observed lesion shares characteristics of a proliferative lesion with mounds or folds of bone growth with a 'starburst' or 'sunburst' pattern and apparent porosity along with location of the condition with osteosarcoma and does not present any characteristics osteosarcoma is not known to have, while conditions Enchondroma, Chondroma, Chondrosarcoma, and Ewing's Sarcoma could also be possible causes. The lesion observed does not fit with the known criteria for conditions Enchondroma, Chondroma, Chondrosarcoma, and Ewing's Sarcoma due to the areas affected by these conditions as well as the morphology of said conditions.

Table 1

Pathological Conditions:	Age Affected:	Area Affected:	Rarity:	Description of Morphology:	Possible Condition? (Y/N)
(Comparatively): Individual 1154	12-13 years old	Right Fifth Metatarsal	N/A	Proliferative lesion with mounds or folds of bone growth with a ‘starburst’ or ‘sunburst’ pattern and apparent porosity	N/A
Unicameral bone cyst	Young children or adolescents but can occur in adults	Proximal humerus, proximal and distal femur, proximal and distal tibia, and proximal fibula	Common	Round/oval fluid-filled single cavity lined by thin membrane of poorly vascularized osteogenic mesenchyme, osteoclastic resorption inside and osteoblastic bone deposition outside; pathological fractures	No, due to localization and morphology
Aneurysmal bone cyst	Older children and adolescents	Long bones and spine	Common	Multilocular, but different compartments, wall consists of highly vascular connective tissue with numerous giant cells	No, due to localization and morphology
Congenital epidermal inclusion cyst	Any age	Skull, but mainly parietal bone	Fairly rare	Small, round cyst appearing in diploe	No, due to localization and morphology
Traumatic epidermal inclusion cyst	Any age	More common in digital phalanges than pedal	Uncommon	Central cavity, no more than one centimeter in diameter, with/without evidence of healed fracture	No, due to localization and morphology

Enchondroma	Later childhood through to middle age	Digital phalanges, metacarpals, humerus, femur, pedal phalanges, metatarsals, tibia, fibula, and ulna	Common	Partly destroys cancellous bone; if large, scalloped inner cortex of long bones; small bones of hands/feet: outer contour may distort and expand, revealing thin, new cortical shell, which may be perforated	Considered but eventually excluded
Juxtacortical chondroma	Later childhood through to middle age	Metadiaphyseal area of large, long bone of extremity	Rare	Cup-shaped depression of underlying cortex with elevated cortical lip near defect; separated from interior of bone by distinct sclerotic border; central portion may calcify and/or ossify	No, due to localization and morphology
Osteoid osteoma	Older children and young adults	Long bones of extremities	Not infrequent	Small, tumor-like lesion consisting of poorly mineralized woven bone	No, due to localization
Chondromatosis (Ollier's Disease)	Early childhood	Various parts of enchondrally ossified skeleton, most frequent in bones of extremities, including hands and feet	Rare	Cartilage tumors: ballooning deformities bordered by thin cortical shell; growth of large cartilage masses results in diminished growth, bowing deformities, and widening of metaphysis due to delayed remodeling	No. due to localization and morphology
Chondroblastoma	Adolescents and young adults	Epiphyses of long bones (distal femur, proximal tibia, proximal humerus, distal tibia, proximal femur, calcaneus, talus, ilium, and ischium)	Fairly rare	Purely lytic lesion several centimeters in diameter (Only bone tumor to arise and confined to epiphysis or apophysis)	No, due to localization and morphology

Chondromyxoid fibroma	Adolescents and young adults	Metaphyseal area of long and short tubular bones, mainly of lower extremity; most common bone involved: tibia	Rare	Neoplastic proliferation of fibroblastic cells produce large amounts of mucoid matrix; giant cells scattered throughout	No, due to localization and morphology
Osteoma	Any age	Mainly skull	Common to uncommon	Benign borderline-neoplastic lesion consists of mostly dense lamellar bone with vascular channels, practically without marrow spaces, many shapes/sizes/amounts (I.E., button osteomas and horse-shoe-shaped)	No, due to localization and morphology
Osteoblastoma	Adolescents and young adults	Long bones	Rare	Similar to osteoid osteoma but may grow to considerable size	No, due to localization and morphology
Chondroma	See Enchondroma and Juxtacortical chondroma	See Enchondroma and Juxtacortical chondroma	See Enchondroma and Juxtacortical chondroma	See Enchondroma and Juxtacortical chondroma	Considered but eventually excluded
Fibrous cortical defect	Children over two years old	Metaphyseal cortex of long bones; most commonly involved area: distal metaphysis of femur; proximal tibia, proximal and distal fibula, proximal femur, distal tibia, humerus, radius, and ulna	Common	Longer than wide and may be multiloculated; adjacent portion of cortex may be sclerotic, and layer of dense bone separating it from medullary space; multiple and symmetrical lesions; spindle-shaped mesenchymal cells and giant cells	No, due to localization and morphology

Cartilaginous exostosis (osteochondroma)	Beginning in childhood	In proximity to growth plate on metaphyseal surface of long bones, distal metaphysis of femurs and proximal metaphysis of tibias	Common	Rounded outgrowth on periosteal surface moving towards final shape greatly modified by mechanical stresses; elongated polypoid structures with bulbous tips pointed away from joint; fractures not uncommon; proximal humerus: may remain broad based and bulky; pelvis: cauliflower-like osteochondrous masses	No, due to localization and morphology
Chordoma	Individuals above 40 years of age	Skull base to tip of coccyx, through entire spine	Rare	Large, lytic defects in spheno-occipital portion of skull base or sacrococcygeal area centered midline	No, due to localization and morphology
Non-ossifying fibroma	Later childhood and adolescents	Same as fibrous cortical defect	Less common than fibrous cortical defect	Distinct, often scalloped, bony shell from medullary tissue; thin long bone: may transect full diameter; pathological, diagonal, fracturing, especially in weight-bearing bones; may reach length of ten centimeters	No, due to localization and morphology
Cortical desmoid	Adult	Long and short tubular bones	Common	Scalloped cortical defect filled with tough mature collagen, separating cortical shell at deep margin	No, due to localization and morphology

Giant cell tumor (osteoclastoma)	Mostly less than 40 years of age (most commonly adolescents and young adults)	Most often found in long bones; distal femur, proximal tibia, distal radius, and proximal humerus	Common	Destroys spongiosa and original cortex, formation of thin, new, periosteal cortical shell in expanded position; small, rounded perforations and reinforcing ridges; excavates epiphysis and approaches articular surface without penetrating joints; transition zone into intact cortex on diaphyseal end sharp and narrow; pathological fractures not uncommon	No, due to localization and morphology
Hemangioma	Older individuals (true hemangiomas in spine affect younger ages)	Vertebrae (most commonly thoracic vertebrae but true hemangiomas may appear in the vertebrae or cranial vault)	True hemangiomas rare, but vertebral ones are common	Solitary or multiple lesions; pathological fractures; true hemangiomas: radial arrangement of coarse diploic trabeculae around large vascular channels, round lesions, several centimeters in diameter; expands outward with circular lytic margin in periphery; in long bones, loculated lytic and/or sclerotic lesions (not distinct enough for ID in dry bone)	No, due to localization and morphology

Meningioma	Any age	Skull	Uncommon to rare	Massive response of reactive bone in form of radiant spicules; more osteosclerotic; unusually large arachnoid granulation creates deep smooth-walled cranial vault defects; lined by thin internal table	No, due to localization and morphology
Chondrosarcoma	Late adolescence to adult age	Metaphysis of long bone, proximal and distal metaphysis of the femur, the proximal metaphysis of the humerus and the pelvis	Rare	Nodular, destroying cancellous bone and causing endosteal scalloping of cortex by pressure erosion; mature forms undergo spotty calcification and enchondral ossification	Considered but eventually excluded
Ewing's Sarcoma	Childhood and adolescence	Long bone of extremity or pelvic bone	Common (third most frequent)	Resorption by Haversian canals leads to lamination of cortex; spreads into/through periosteum, reactive bone growth of surface parallel or radiant type; metastasize to other bone	Considered but eventually excluded

Osteosarcoma	Adolescents and young adults	Distal femoral metaphysis, followed by proximal tibial metaphysis and proximal humeral metaphysis; predilects long bones of extremities, rarely involves cancellous bones, small tubular bones of extremities, or skull (mandible most often involved)	Common	Destroys normal bone and extends through cortex into nearby soft tissue; appearance depends on amount of mineralized bone formation; almost purely lytic forms to massive production of sclerotic tumor bone; woven bone produced, occurs in sheets and masses without architectural arrangement of trabeculae; extracortical portion may exhibit radiant alignment of tumor bone (sunburst); slow growing and may produce large extraosseous masses of dense bone	Yes
---------------------	------------------------------	--	--------	--	-----

(Ortner, 2003)

Discussion

The careful analysis of skeletal lesions of a set of remains allows for a piece of research that may further research into a group of people or a pathological condition and its rates in a certain period. Detailed descriptions of skeletal lesions become essential at this analytical level, particularly for collections not easily accessible or for collections of multiple individuals. Focusing on the individual level has several benefits, but further research is always required. A

population level approach may provide a model for approaching ancient diseases that highlights the importance of population-level analysis. The abnormal lesion present showing the morphology of osteosarcoma combined with the age of Individual 1154 and the presence of other pathological conditions can lead one to draw several conclusions, including the fact that this person could have suffered from nutritional deficiencies due to enamel hypoplasia evident on a mandibular canine and trauma or work-related stress or injuries (G. Dabbs, personal communication, June 2, 2021). Further, the location and morphology of the lesion on the metatarsal in question are consistent with osteosarcoma of the metatarsal, therefore, making osteosarcoma the most probable cause.

This differential diagnosis provides a unique look into osteosarcoma of ancient Egypt as well as into the global distribution of osteosarcoma. While this may not be the first case of osteosarcoma in Egypt, this may be the first case of osteosarcoma in middle Egypt or Amarna, Egypt as research into the topic only found cases from Kom el Shougafa, in Alexandria. Further, there are other cases of osteosarcoma that are far older than either the Ruffer case (Strouhal, 1976) or the case of Individual 1154, with the oldest known case being that of early human ancestor dated to 1.8–1.6 million years old (Odes et al., 2016). The case of Individual 1154 adds to the general understanding of osteosarcoma and, cancers as a whole, during this time and location.

Conclusions

This study aimed to macroscopically analyze the abnormal morphology of Individual 1154's right fifth metatarsal to provide a differential diagnosis. Individual 1154's remains were excavated from the North Tombs Cemetery at Amarna. Individual 1154 was wrapped in textile and a mat of plant fiber, consistent with other burials in the cemetery. The skeleton was nearly

complete and was in an excellent state of preservation. Pathological analysis shows a non-spinal fracture, periostitis/otitis, degenerative joint disease signs of anemia, and an abnormal bony lesion on the fifth right metatarsal. There is a fusion anomaly of the first cervical vertebra.

Macroscopic analysis of the lesion was observed to be reasonably consistent with osteosarcoma morphology, including an irregular growth pattern showing mounds and folds of abnormal bone formation combined with a 'starburst' pattern and apparent porosity. As stated previously, a comparative approach was used to provide a differential diagnosis of the condition in question; however, a biological approach that explores the pathophysiology of skeletal lesions seen in the individual, which identifies underlying biological processes that could produce the lesion observed and a radiographic analysis would be suggested, if plausible. These approaches were not explored during the course of this analysis due to lack of supportive funds and access to the necessary equipment needed to perform these types of analyses.

In context, this finding may fit into a future or ongoing study of cancers in the ancient world, specifically in ancient Egypt or in Amarna, Egypt. This study highlights the importance of implementing paleopathological analyses on a single case or set of remains. It may provide insight into how cancers or pathological conditions were treated and the information needed to establish a rate of cancers in ancient Egypt. Further research is warranted to contextualize the evidence presented here, and we hope that our approach leads to continued efforts to establish a study on the rate of cancers in the ancient world and Egypt as well as leads to more differential diagnoses on singular individuals or cases to broaden knowledge on how pathological conditions affected individuals and communities.

References

- AlQahtani, S., Hector, M., & Liversidge, H. (2010). Brief communication: The London atlas of human tooth development and eruption. *American Journal of Physical Anthropology*, *142*(3), 481-490. doi:10.1002/ajpa.21258
- Aufderheide, A. C., Rodríguez-Martín, C., & Langsjoen, O. (2016). *The Cambridge Encyclopedia of human paleopathology*. Cambridge University Press.

Buikstra, J. E. (1977). Differential diagnosis: an epidemiological model. *Yearbook of Physical Anthropology*, 20, 316-328.

Buikstra, J. E. (2019). Ortner's identification of pathological conditions in human skeletal remains. Academic Press, an imprint of Elsevier.

Buikstra, J. E., & Roberts, C. A. (2012). *The global history of paleopathology : pioneers and prospects* . Oxford University Press.

Dabbs, G. R. (2020, August 15). Estimating the sex of Ancient Egyptian skeletal remains: Methods from Tell el-Amarna. Retrieved July 25, 2022, from <http://anthropology.uw.edu.pl/>

Dabbs, G. (2019). Bioarchaeology of the non-elite North Tombs Cemetery at Amarna: A preliminary assessment of the non-elite individuals of the North Tombs Cemetery at tell el-amarna, Egypt. *Bioarchaeology International*, 3(3), 174-186. doi:10.5744/bi.2019.1012

Kemp, B. (2017). Tell el-Amarna, spring 2017. *The Journal of Egyptian Archaeology*, 103(2), 137–151. <https://doi.org/10.1177/0307513317749457>

Erdogan, K. E., Pacheco, M., Gambarotti, M., Magagnoli, G., Sbaraglia, M., Frisoni, T., Righi, A., & Dei Tos, A. P. (2021). Usefulness of β -catenin expression in the differential diagnosis of osteosarcoma, osteoblastoma, and Chondroblastoma. *Virchows Archiv*, 479(3), 529–535. <https://doi.org/10.1007/s00428-020-03004-2>

Ferrante di Ruffano, L., & Waldron, T. (2018). On the importance of considering disease subtypes: Earliest detection of a parosteal osteosarcoma? differential diagnosis of an

osteosarcoma in an Anglo–Saxon female. *International Journal of Paleopathology*, 21, 128–137. <https://doi.org/10.1016/j.ijpp.2016.12.001>

Jiang, L., Liu, J., Wei, Q., & Wang, Y. (2020). KPNA2 expression is a potential marker for differential diagnosis between osteosarcomas and other malignant bone tumor mimics. *Diagnostic Pathology*, 15(1). <https://doi.org/10.1186/s13000-020-01051-6>

Kemp, B. J. (2015). *The City of Akhenaten and nefertiti: Amarna and its people*. London: Thames & Hudson.

Mitchell, P. D., Dittmar, J. M., Mulder, B., Inskip, S., Littlewood, A., Cessford, C., & Robb, J. E. (2021). The prevalence of cancer in Britain before industrialization. *Cancer*, 127(17), 3054–3059. <https://doi.org/10.1002/cncr.33615>

Odes, E. J., Randolph-Quinney, P. S., Steyn, M., Throckmorton, Z., Smilg, J. S., Zipfel, B., . . . Berger, L. R. (2016). Earliest hominin cancer: 1.7-million-year-old osteosarcoma from Swartkrans Cave, South Africa. *South African Journal of Science*, Volume 112(Number 7/8). doi:10.17159/sajs.2016/20150471

Ortner, D. J. (2003). *Identification of pathological conditions in human skeletal remains*. Amsterdam: Academic Press.

Ruffer, M. A. (1921). *Studies in the Palaeopathology of Egypt*. Chicago, IL: University of Chicago Press.

Shaw, I. (2014). *Oxford History of Ancient Egypt*. Oxford University Press.

- Stevens, A., Dabbs, G. R., Bos, J. E., Mérat, A., Garnett, A., & Tully, G. (2020). Tell el-Amarna, Autumn 2018 to Autumn 2019. *The Journal of Egyptian Archaeology*, 106(1-2), 3-15.
doi:10.1177/0307513320973678
- Stevens, A. (2018). Anna Stevens and Gretchen Dabbs, The North Tombs Cemetery excavations and skeletal analysis. *Journal of Egyptian Archaeology*, 1–13.
- Stevens, A. (2017). Death and the city: The cemeteries of Amarna in their urban context. *Cambridge Archaeological Journal*, 28(1), 103-126. doi:10.1017/s095977431700059
- Strouhal, E. (1976). Tumors in the remains of ancient Egyptians. *American Journal of Physical Anthropology*, 45(3), 613-620. doi:10.1002/ajpa.1330450328
- Tuli, S. M. (2016). Differential diagnosis. Tuberculosis of the Skeletal System (Bones, Joints, Spine and Bursal Sheaths), 234–234. https://doi.org/10.5005/jp/books/12726_22
- Waldron, T. (2021). *Palaeopathology*. Cambridge University Press.