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COMPUTED TOMOGRAPHY IN AID OF OSTEOARCHEOLOGY – A CASE STUDY OF MUMMIFIED REMAINS OF VICAR NIKOLAUS RUNGIUS

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INTRODUCTION

Non-invasive imaging methods are beneficial in mummy research. Both two-dimensional radiographs and three-dimensional data from computed tomography (CT) are considered useful. This case study aims to explore the potentials of CT scanning naturally mummified human remains in Finland. The remains of late vicar of the Kemi parish in Northern Osthrobotnia, Nikolaus Rungius were the first to be examined using CT scanning to assess the preservation and pathological conditions. The corpse had mummified by natural freeze-drying almost 400 years ago. This study functions as a pilot study to evaluate the applicability of CT in the anthropometric and paleopathological study of naturally formed Finnish mummies. This new project has a broader approach to living conditions and social hierarchy in the Northern Osthrobotnia region in the past. Another aim of it is to form a digital database of the mummified remains before they decompose.

Natural mummification through freeze-drying is fairly common in the crypt burials of old churches in northern Finland. This was due to the cool and well-ventilated conditions under the church floors (Núñez et al. 2011). Nikolaus Rungius (ca. 1560–1629) was buried under the floor of the Church of Saint Mikael in the parish of Keminmaa, former Kemi. This crypt was probably used for burials since the church was built in the mid-16th century. Burials in the crypt continued until 1870 despite the ban of church burials in 1822. A fair proportion of the individuals buried in the crypt have mummified in varying degrees. The most famous mummy in the crypt is vicar Rungius, a well-known figure in the local folklore (Paavola 1998).

METHODS

A considerable amount of information, such as sex and age at death, can be acquired through external examination of the mummy. Signs of trauma and pathological skin lesions, which can be used when looking for cause of death, can be observed. Also observations of preservation and external *post mortem* damage of the remains can be made. In inspection of the internal parts also muscular and visceral aspects can be taken into account when assessing the health and possible cause of death of the individual.

Traditionally internal examination has been made by means of autopsy or endoscopy, which lead to at least partial destruction of the mummy. In this study the objective is to utilize 3-dimensional full body CT scan as a non-invasive method to study the mummy internally. CT scanning is used in clinical medicine for diagnostic and research purposes. In institutions, such as museums, CT scanning has also been used to document and study mummified remains without damaging them.

The mummified remains of Nikolaus Rungius were scanned in April 2011 using the clinical CT scanner of the Oulu University Hospital. The scan protocol was performed using the section width of 0.6 mm, reconstruction field of view of 665 mm and image matrix of 512 x 512 resulting image voxels of size 1.3 mm x 1.3 mm x 0.6 mm. These parameters provide resolution high enough to detect fairly small details. This enables observing physical measurements and identifying pathological conditions (Fig. 1).

Stature was measured from the CT scan from the base of the calcaneus to the top of the cranium. One centimetre was added to compensate the shrinkage of the soft tissue due to mummifica-

Fig. 1. A full-body CT scan of vicar Rungius' mummy. White matter (encircled) was interpreted as kidney stones.

tion. Body mass was approximated from stature and bi-iliac breadth using cylinder model (Ruff et al. 2005). Pathological conditions were observed using clinical diagnostic procedure. The effects of decomposition were considered while conducting the examination.

RESULTS

Preservation

Right distal arm from the elbow joint and six cervical vertebrae were missing (Fig. 2). Soft tissue had preserved in most parts except the scalp, were it had decayed revealing the sutures in the calotte. Also skin and the other soft tissue of the neck were missing. The head had separated from the postcranial body at some point after death and had been placed back without the cervical part. Age estimation based on the suture closure (Mendl & Lovejoy 1985) is consistent with archival evidence of the age at death. There was only a minimal amount of soft tissue preserved inside the cranium consisting mainly of the remains of meninges. Similarly only membrane structures had preserved of the heart and lungs while the ventricles of the heart were still identifiable. Other intestines, such as muscles were even poorer preserved. However, muscles could be identified from their tendons. Furthermore, the mummy had suffered external *post mortem* damage to the right side of the lower back area where some soft-tissue was missing.

Fig. 2. The head had been placed on the trunk as most of the cervical vertebrae are missing.

Anthropometric measurements

Stature measured from CT scans with additional soft tissue to allow difference between living and freeze-dried state of the body was 163 cm. However, as the mummy is missing six cervical vertebrae (C1–C6) this does not represent the true living stature. Height of the missing cervical vertebrae needs to be added. These cervical vertebrae constitute an average of 9.2 cm among men and additionally of 3.5 cm for the intervertebral disks and other soft tissue. Adding the length of missing cervical part and soft tissue to the measured length the estimated stature is 176.7 cm. This stature was used in body weight estimation with cylinder method. Bi-iliac breadth was measured 28 cm from CT scans. For reconstructing weight this measure needs to be converted into living bi-iliac breadth. This is achieved by following formula: living bi-iliac breadth = 1.17 x skeletal bi-iliac breadth - 3 cm. Using these measurements body weight estimate of 75 kg was received. However, this is only an approximation of the body size individual is meant to weigh. There can be considerable amount of fluctuation in muscular and especially in fatty tissue.

Pathological conditions

Teeth were relatively healthy. Both 3rd maxillary molars had fallen or pulled off well before death. The 2nd right maxillary molar had fallen off, probably *post mortem*. Dentition exhibited moderate periodontitis and minor calculus formation. Only 3 caries lesions were observed. The flat molar wear-pattern and the dental condition suggest protein rich diet.

Indication of Forester's disease (diffuse idiopathic skeletal hyperostosis, DISH) was found in the thoracic spine of the mummy (Fig. 3). Also a clear compression fracture of a thoracic vertebra was observed which could possibly be symptomatic of spondylodiscitis, an infection of the intervertebral disc. The articular surfaces of the joints were in relatively good condition in comparison to the current medical patients of the same age.

In the acetabula, which are articulations for femur in the pelvis, moderate osteophyte development (bone formation in the joints) was detected. Also the subchondral bone in the medial compartments of both knees was slightly sclerotic, and small marginal osteophytes were observed. These findings can be indicative of minor medial osteoarthritis of the knee which is often related to obesity. In tarsal region (the ankles and feet), direct signs of osteoarthritis were not detected but some small entesophytes (bone formation in the muscle and tendon attachments) in the calcaneal bones were discovered.

In the thoracic cavity at the region of the left lung, denser granular matter and some calcified substance were observed. This could indicate calcification of the left pleura. Two additional calcifications (Fig. 1), possibly kidney stones, were found in the both sides of abdominal cavity. However, the site is not precisely correct. Calcification on the right side may also originate from outside of the body because of the external destruction in this area.

Also some non-pathological traits were documented in the skeleton. Vicar Rungius had a skeletal feature called *torus palatinus* in his palatine bone. This is a protuberance of bone in the hard palate. This feature is a non-metric trait. The differences in its prevalence between populations tell about genetic affiliations. For example, this trait was a common feature in the population of 17th and 18th century Oulu (50–60%) (Ojanlatva et al. 2000). However, vicar Rungius comes from Loimaa in southern Finland where the prevalence of the trait is unknown.

Fig. 3. A manifestation of DISH (diffuse idiopathic skeletal hyperostosis) and a compression fracture were found in the thoracic spine of the mummy.

DISCUSSION

CT scanning proofed to be a functional tool in the study of Finnish mummies. From the information provided by the CT scans of the mummy we could assess preservation and health as well as the visual appearance of vicar Rungius.

At the time of death vicar he was about 60–70 years old. This means that he reached longevity in comparison to his contemporaries. Stature estimation indicated that he was fairly large man measuring almost 180 cm. He was tall compared to his contemporaries in the 17th century when average stature for men was under 170 cm. The estimated weight of about 75 kg is somewhat low, and we feel that it does not correspond to the actual weight of vicar Rungius. We consider he was obese at the time of death based on external appearance as well as information gained of his pathological conditions. He was buried hands placed over his stomach. The left arm has dried on this position. After decay of internal organs in the abdomen and shrinkage caused by freeze-drying this hand was left hanging in the air above the mummy giving away a line of a fairly generous stomach (Fig. 4). Furthermore, DISH found in the thoracic spine of the mummy is often related to type II diabetes and obesity. According to

Fig. 4. After the decomposition of the viscera and adipose tissue of the stomach the left arm is still hanging in the position it was once placed. The right arm is missing distally from the elbow joint.

archaeological material from England this condition was more common among the clergy than the peasants due to better living conditions of the former (Waldron 1985). It is quite probable that in the 17th century Finland priests had better access to food and good living conditions, and reached longevity more likely than the common people.

When assessing the cause of death cardiovascular problems are a probable candidate as they are related to old age and obesity. However, in absence of the internal organs it is difficult to confirm the diagnosis. Vicar Rungius may also have died of septicemia caused by the infection observed in his spine. Until recently in Western societies a common cause for spondylodiscitis was skeletal tuberculosis. When pathogen causing it (*Mycobacterium Tuberculosis*) spreads from lungs to the spine it leads to collapse of the vertebrae and formation of a hunch-back known as Pott's spine. Pott's spine is a typical manifestation of skeletal tuberculosis. Alternatively, the pathogen which caused the vertebral lesion could have been for example staphylococcus. However, if left untreated spondylodiscitis can cause septicemia and even the death.

Possible calcification of pleura might indicate inflammation in the lung due to, for example, pneumonia, which can be caused by *Mycobacterium Tuberculosis*. Also, Rungius had possible case of kidney stones which have been related to obesity (Taylor et al. 2005), but also renal tuberculosis (Eastwood et al. 2001). Considering the collapsed vertebra and the possible kidney stones, vicar Rungius may have been tuberculotic.

The CT scans revealed that almost all of the cervical vertebrae and distal part of right arm of the mummy were missing although the reason for this remained unresolved. It is unlikely that only the area around the cervical spine would have decomposed. Neither were there any indications of intentional violence to the neck before or after death. The area of cervical vertebrae might have been damaged, for example, when the mummy was moved into new coffin after the old one had decayed.

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