European Journal of Radiology Open 3 (2016) 172–181

Contents lists available at ScienceDirect

European Journal of Radiology Open

journal homepage: www.elsevier.com/locate/ejro

From first to latest imaging technology: Revisiting the first mummy investigated with X-ray in 1896 by using dual-source computed tomography

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ARTICLE INFO

Article history:
Received 30 June 2016
Accepted 2 July 2016

Keywords:
X-ray
Dual-energy computed tomography
Child mummy
Ancient Egypt
Pectus excavatum deformity
Hepatomegaly

ABSTRACT

Purpose: The aim of this study was to systematically reinvestigate the first human mummy that was ever analyzed with X-ray imaging in 1896, using dual-source computed tomography (DSCT) in order to compare the earliest and latest imaging technologies, to estimate preservation, age at death, sex, anatomical variants, paleopathological findings, mummification, embalming and wrapping of the child mummy from ancient Egypt. Radiocarbon dating was used to determine the mummy's age and to specify the child's living period in the Egyptian chronology.
Material and methods: The ancient Egyptian child mummy is kept in the *Senckenberg Museum of Natural History* in Frankfurt am Main, Germany. An accelerator mass spectrometer (MICADAS) was used for radiocarbon dating. DSCT was performed using a 2 × 64 slice dual-source CT system (Siemens Healthineers, Forchheim, Germany). A thorough visual examination of the mummy, a systematic radiological evaluation of the DICOM datasets, and established methods in physical anthropology were applied to assess the bio-anthropological data and the post mortem treatment of the body.
Results: Radiocarbon dating yielded a calibrated age between 378 and 235 cal BC (95.4% confidence interval), corresponding with the beginning of the Ptolemaic period. The mummy was a male who was four to five years old at the time of death. Remnants of the brain and inner organs were preserved by the embalmers, which is regularly observed in ancient Egyptian child mummies. Skin tissue, inner organs, tendons and/or musculature, cartilage, nerves and vasculature could be identified on the DSCT dataset. The dental health of the child was excellent. Anatomical variants and pathological defects included a congenital *Pectus excavatum* deformity, hepatomegaly, Harris lines, and longitudinal clefts in the ventral cortices of both femora.
Conclusion: Our results highlight the enormous progress achieved form earliest to latest imaging technology for advanced mummy research using the first human mummy investigated with X-ray. With the application of DSCT, detailed knowledge regarding age at death, sex, diseases, death, and mummification of a child from Ptolemaic Egypt are revealed while considering the temporary rites of body treatment and burial for children.

1. Introduction

A few months after the discovery of X-rays by Wilhelm Conrad Roentgen in November 1895, the physicist Walter Koenig conducted the first radiographic investigation of mummified remains at the *Physical Society of Frankfurt a.M.*, Germany. The results of this investigation were published in March 1896 in the monograph

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http://dx.doi.org/10.1016/j.ejro.2016.07.002

entitled *14 Photographs with X-rays taken by the Physical Society of Frankfurt am Main* [1]. The X-rayed objects included a bandaged ancient Egyptian child mummy from the *Senckenberg Museum of Natural History* (inventory number ÄS 18).

The earliest radiographic investigations of mummies focused on discovering amulets and jewelry within the body cavities, evaluating the wrappings, and determining whether human or animal bones were represented in bandages and coffins [2,3]. However, the application of the novel X-ray technique included shortly afterwards the aim of assessing anthropological and paleopathological knowledge about the mummified individuals [2,4–6].

The abilities of paleoradiology were greatly enhanced with the introduction of computed tomography (CT) in the early 1970s, allowing non-invasive analysis of body cavities (e.g. cross-section) for the first time [7]. Peter Lewin and Derek Harwood-Nash performed the first axial CT examination of mummified tissue from ancient Egypt at the Hospital of Sick Children in Toronto in 1976 [7,8]. They investigated the desiccated brain of Nakht, a 21st dynasty mummy of an adolescent male in the collection of the Royal Ontario Museum in Toronto; this was followed by the first complete body scan on the female mummy of Djedmaatesankh, from the 22nd dynasty, housed within the same museum [9].

CT imaging is now widely used in mummy research in order to non-invasively assess a variety of parameters, including bone and soft tissue preservation, post-mortem damages, artifacts, mummification technique, embalming, age at death, sex, diseases, trauma, cause of death, medical intervention, and artificial cranial deformation [5,10].

In this case study, the ancient Egyptian child mummy from *Senckenberg Museum of Natural History*, which was the first mummy ever investigated with X-rays, was reanalyzed in an interdisciplinary approach using dual-source computed tomography (DSCT), radiocarbon dating, and physical anthropology.

2. Material and methods

2.1. Provenance and outer appearance

In 1817, the natural scientist and Africa explorer Eduard Rueppell collected numerous objects from ancient Egypt on his first trip to Africa, including small size Aegyptiaca, mummies and sarcophagi. Purchasing these objects was possible due to personal funding of the explorer and with the support of ingenious collectors. At first, the objects were transferred to the *Senckenberg Museum of Natural History* in Frankfurt am Main, Germany, then afterwards to the *Historical Museum Frankfurt*. Later, the *Historical Museum Frankfurt* left the Aegytiaca to the *Liebieghaus* and returned the mummies, sarcophagi and some animal trophies to the *Senckenberg Museum of Natural History* in 1970. The child mummy (Fig. 1) is about 80 cm in length, with a maximum width of 24 cm on shoulders and maximum depth of 16 cm on the head. There is no iconographical or textual decoration to facilitate identification or chronological dating of the mummy. Both arms are aligned laterally to the body, while the left hand is displaced slightly anteriorly on the left thigh. The head, arms, fingers and legs are individually wrapped with textile (probably linen) in tightly packed layers. The body, however, is incompletely covered, likely due to post-preservation removal of some wrapping material. The cranial vault is largely free of textile tissue and the preserved layers are much thinner than those of the body. Wrapping material is also absent on the back of the left hand, the left thumb, the left second phalanx and on all phalanges of the right hand. The left thigh, left lower leg, and right lower leg are partially free of soft tissue and wrappings. All tissue damage was probably caused postmortem. The textile wrappings are soaked with dark bitumen based embalming liquids, especially on the head and extremities.

Fig 1. Photography of the bandaged ancient Egyptian child mummy from the *Senckenberg Museum of Natural History* in Frankfurt a.M. (inventory number ÄS 18).

2.2. Radiocarbon dating

For estimating the post mortem interval (PMI) of the mummy, approximately 1 g of soft tissue was sampled in a minimal invasive way by using a previously existing hole in the textile wrap-