



CT checklist and scoring system for the assessment of soft tissue preservation in human mummies: application to catacomb mummies from Palermo, Sicily

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ABSTRACT

In this study we applied the recently developed “Checklist and Scoring System for the Assessment of Soft Tissue Preservation in Human Mummies” to catacomb mummies from Palermo, Sicily.

Data from twenty-three full-body computed tomography (CT) examinations were available. These consisted of seventeen adults and six children dating from the late 18th to the late 19th centuries AD. Seventeen of these mummies were anthropogenically mummified, and six spontaneously.

Based on the checklist and scoring system, soft tissue preservation varied between both mummification groups, among mummies with the same type of mummification, and within individual mummies at different anatomical locations.

Checkpoints of the main category “A. Soft Tissues of Head and Musculoskeletal System” were clearly more frequent than checkpoints of the main category “B. Organs and Organ Systems”. Among the anthropogenic mummies, intra-arterial filling achieved the highest preservation status of organs and organ systems. Despite the small sample size, the statistical evaluation showed significant differences between mummification types, with the highest soft tissue preservation found in anthropogenic mummies.

Application of the “Checklist” allowed a standardized assessment and documentation of the soft tissue preservation of these mummies. The “Scoring System” facilitated a comparison among mummification groups and mummies by means of numeric values.

1. Introduction

Human mummies are defined as remains with preservation of non-bony tissues (Aufderheide, 2003; Lynnerup, 2010; Lynnerup 2007). Non-bony soft tissues play an important role in paleopathology and increase the range of findings, and diagnoses can be established beyond those possible by osteological study alone (Aufderheide, 2003; Aufderheide, 2000). Soft tissue remains express in large part the preservation status of a mummy. Soft tissues may include foreign bodies and materials as a result of anthropogenic mummification procedures, indicating mortuary practices and burial rites (Gostner et al., 2013; Hawass et al., 2012; Lynnerup, 2010; Panzer et al., 2010; Wade et al., 2012). Furthermore, soft tissue remains may reveal pathologies of single structures or allow the diagnosis of systemic diseases, and in rare cases indicate the possible cause of death (Aufderheide, 2000; D’Anastasio et al., 2010; Gostner et al., 2011; Haas et al., 2015; Hawass

et al., 2012; Murphy et al., 2003; Nerlich et al., 1997; Panzer et al., 2014; Panzer et al., 2013a; Piombino-Mascali et al., 2014; Thompson et al., 2013; Zink et al., 2004).

The first computed tomography (CT) examination of an Egyptian mummy was reported in 1979 (Harwood-Nash, 1979). Since then, CT has become the “gold-standard” for human mummy studies because of its non-destructive nature, its high spatial resolution and image contrast, and the various post-processing modalities (Beckett, 2014; Cesarani et al., 2003; Hoffman et al., 2002; Lynnerup, 2007; O’Brien et al., 2009; Öhrström et al., 2015; Öhrström et al., 2013; Panzer et al., 2013b; Previgliano et al., 2003). The objects of this study were full-body CT examinations of mummies from the Capuchin Catacombs of Palermo, Sicily. These catacomb mummies show a remarkable heterogeneous preservation status of soft tissues. Different postmortem treatments were applied to the bodies for interment in the crypt. The majority of bodies underwent a spontaneous-enhanced mummification.

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Table 1
Radiological and macroscopic signs of anthropogenic mummification in seventeen cases.

Case	P1	P2	P3	P4	P8	P9	P11	P12	P14	P21	P27	P5	P6	P7	P17	P20	P22
Age	a	a	a	a	a	a	a	a	a	a	a	c	c	c	c	c	c
Sex	m	m	m	m	m	m	m	m	m	m	m	f	m	f	m	m	m
Foreign bodies																	
Eyes	+	+	-	-	+	+	+	-	-	+	-	+	+	+	-	+	+
Nose	+	+	+	+	+	+	+	-	+	+	-	+	-	+	+	-	-
Mouth	-	+	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-
Filling																	
Thorax	-	-	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-
Abdomen	+	-	+	-	-	+	-	-	+	-	-	-	-	-	-	-	-
Rectum	+	-	+	-	-	-	+	-	-	+	+	-	-	-	-	-	-
Intraarterial	+	+	-	-	-	-	-	+	-	+	-	+	-	-	-	+	-
Incisions																	
Neck	+	-	-	-	-	-	+	+	-	+	-	+	+	-	-	+	-
Abdomen/Chest	+	-	+	+	+	+	-	-	+	-	-	-	-	-	+	-	-
Thigh	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

A: adult, c: child, m: male, f: female.

To promote desiccation, the corpses were laid on ceramic grids in small rooms, which allowed bodily fluids to drain away. The rooms were then sealed for about a year, after which time the corpses were exposed to the air, washed with vinegar, and dressed. Some bodies were preserved with anthropogenic methods, such as evisceration and arterial injection with special chemicals; preservatives containing arsenic and mercury were popular in the 19th century (Aufderheide, 2003; Fulcheri, 2005; Marinozzi and Fornaciari, 2005; Piombino-Mascalì, 2014; Piombino-Mascalì et al., 2010). Further signs of anthropogenic methods included the placement of foreign materials into the orbits and the nasal and oral cavities, as well as filling of the thoracic, abdominal, and rectal cavities with foreign materials (Panzer et al., 2010). Several environmental conditions in the crypt such as the low humidity, a cool temperature, and good ventilation that derived from perpetually open windows, may have also contributed to the long-term preservation of the bodies (Panzer et al., 2010).

To evaluate the soft tissue remnants, we used the recently developed “Checklist and Scoring System for the Assessment of Soft Tissue Preservation in CT Examinations of Human Mummies” (Panzer et al., 2015) which allows for a standardized assessment and documentation of soft tissue preservation in full-body CT examinations. The added scoring system facilitates a quantitative comparison of the soft tissue preservation status between single mummies or mummy collections via the total score as well as at the level of the two main categories and the various subcategories.

In previous studies, Aufderheide (2003) and Wittmers et al. (2011) developed a system for recording the preservation of mummies through external inspection that can be applied in cases where no CT examinations are available, such as in remote fieldwork activities. However, this approach does not allow a direct evaluation of the inner structures and organs of a mummy, due to the expected heterogeneity of soft tissue preservation in various anatomical locations and tissue types (Panzer et al., 2015; Wittmers et al., 2011). The checklist was developed following the approach of structured reporting, which is increasingly becoming established in clinical radiology and has resulted in more complete, effective, and consistent radiological reports (Faggioni et al., 2017; Larson et al., 2013; Marcovici and Taylor, 2014). The checklist serves as a tool to guide the radiologist through the main soft tissue structures throughout the body and allows standardized checkpoint acquisition. Therefore, assessment of the preservation status of soft tissues is regarded as the starting point for detection of possible pathological findings of those tissues (Panzer et al., 2015).

Thus, the primary aim of this study was to assess and document the soft tissue preservation status of a sample of mummies from the Capuchin Catacombs via full-body CT examinations in a standardized way using the checklist. A secondary aim was to compare the group of

anthropogenic mummies with the group of spontaneous mummies by means of the scoring system.

2. Material and methods

2.1. Material

Data from twenty-three full-body CT examinations of mummies from the Capuchin Catacombs of Palermo, Sicily, that were performed in December of 2010 were available for this study. These consisted of seventeen adults and six children dating from the late 18th to the late 19th centuries AD. Seventeen of these mummies (fifteen males and two females) were anthropogenically mummified, and six spontaneously (all males). The differentiation between anthropogenic and spontaneous mummification was based upon external and radiological examinations. Indicators for anthropogenic mummification were externally visible incisions and radiologically detectable placement of foreign materials into the orbits, the nasal and oral cavities, the filling of the thoracic, abdominal, and rectal cavities with foreign materials, and the evidence of intra-arterial embalming substances (Table 1) (Panzer et al., 2015; Panzer et al., 2010). All of the other mummies were defined as spontaneous mummies.

The mummies were examined with a mobile CT scanner (LightSpeed Plus, GE Healthcare, Milwaukee, Wisconsin, USA; mobile installation provided by Alliance Medical, Warwick, UK). Full-body CT examinations were performed with a slice thickness of 1.25 mm, an interval of 1.25 mm (and a pitch of 0.75) with 120 kV in a standard algorithm (Panzer et al., 2015; Panzer et al., 2012). Permission for the imaging study was granted by the Order of the Capuchin Friars for the Province of Palermo.

2.2. Methods

2.2.1. Checklist and scoring system

For evaluation of soft tissues the recently developed “Checklist and scoring system for the assessment of soft tissue preservation in CT examinations of human mummies” (Panzer et al., 2015) was applied to all twenty-three full-body CT examinations by the first author, a senior radiologist with seventeen years of experience in clinical radiology and thirteen years in paleoradiology. The checklist is divided into two main categories: “A. Soft tissues of Head and Musculoskeletal System” and “B. Organs and Organ Systems”. The main category A is divided into “A.1. Head” and “A.2. Musculoskeletal Systems” with further subdivisions into “A.2.1. Tendons and/or Musculature”, “A.2.2. Peri- and Intra-articular Soft Tissues” and “A.2.3. Intervertebral Discs”. The main category B is divided into “B.1. Central Nervous System and Peripheral

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