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Radiological evaluation of the evisceration tradition in ancient Egyptian mummies

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ABSTRACT

Descriptions of the preparation of ancient Egyptian mummies that appear in both scientific and popular literature are derived largely from accounts by the Greek historians Herodotus and Diodorus Siculus. Our reliance on these normative descriptions obscures the wide range of techniques practised, and so stifles the study of geographic, chronological, and social variations in the practice. Using published descriptions in the literature for 150 mummies and 3D reconstructions from computed tomography data for 7 mummies, this study compares empirical data with classical descriptions of evisceration, organ treatment, and body cavity treatment. Techniques for accessing the body cavity, removal and treatment of the organs, and treatment of the eviscerated body cavity vary with time period, sex, and status, and are discussed in relation to their treatment in the literature and their radiological appearance. The Herodotean and Diodorean stereotypes, including the restriction of transabdominal evisceration to the elite and cedar oil enema evisceration to commoners, are falsified by the data. The transperineal forms are present only in elites, and chemical evisceration is not apparent at all. Additionally, the dogmatic contention that the heart was universally retained in situ, or replaced if accidentally removed, is also greatly exaggerated.

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Introduction

Evisceration, whether by transabdominal incision, transperineal incision, or anal cedar oil injection, is a well-recognised component of the Egyptian mummification tradition beginning in the Old

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Kingdom. Descriptions of Egyptian mummification, common to popular and academic literature, are derived largely from accounts by the classical authors Herodotus and Diodorus Siculus, particularly as they address the universal retention of the heart and the elite nature of excerebration and abdominal evisceration. Normative descriptions, based on the accounts of these and other late authors, impede the investigation of a wide range of variation in Egyptian mummification techniques.

The goals of this study are (1) to use the classical descriptions as hypotheses for empirical testing, using published descriptions and primary computed tomography (CT) data and (2) to examine temporal, spatial, and social variability in the evisceration tradition.

Variability within and between Egyptian mummification techniques is poorly appreciated in the literature (Nelson et al., 2007; Wade et al., 2011), in spite of some pioneering work done by Strouhal (e.g. 1995), the large-scale radiological survey of UK mummy collections conducted by Gray (1972), and the bioarchaeological survey of Nubia conducted by Smith and Wood-Jones (1910). Despite the high degree of variability apparent in the literature as an aggregate, researchers continue to focus on modern and classical stereotypes rather than on the rich temporal, spatial, and social variability in Egyptian mummification as it evolved across Egypt over the course of more than three millennia.

These stereotypes, however, can be used to formulate a hypothesis that can be empirically tested. If the classical accounts by Herodotus and Diodorus Siculus are correct, then evisceration via abdominal incision should be restricted to the elite, chemical evisceration per anum should be well-represented and be present primarily in commoners' remains, and the heart should be present in the overwhelming majority of eviscerated mummies, at least in the Late and Ptolemaic Periods within which these authors wrote.

This study focuses on CT as the best practice for non-destructive examinations of Egyptian mummies (O'Brien et al., 2009), particularly for the examination of evisceration, owing to its volumetric data and superior contrast resolution. The three-dimensional relationships between anatomical structures and the contiguity (or lack thereof) of tissues are extremely important factors in identifying highly desiccated structures. Likewise, subtle radiodensity differences may provide important information for differentiating among the tissues and materials involved in mummification.

Classical descriptions

Ancient descriptions of the Egyptian mummification process are extremely rare, and are currently limited to two Greco-Roman papyri describing ritual elements that accompany embalming (Goyon, 1972; Sauneron, 1952) and to scenes from the Late Period coffin of Djedbastufankh (Colombini et al., 2000). Brier and Wade (2001) suggest that the details of the mummification process were seldom recorded due to the hereditary and territorial nature of the embalmer's trade (trade secrets), indicated in the Hawara Embalmer's Archive Papyri (Reymond, 1973). Ancient Egyptian literature does, however, provide the intent of the deceased's time in the *w'bt nt wty* ("workshop... of the embalmer priest") and *pr-nfr* ("the place of making perfect") (Shore, 1992, p. 232); to ensure the persistence of "the *sah*, the mummified corpse; *shuwt*, the shadow; *yib*, the heart; and most importantly, the *akh*, the *ka*, [and] the *ba* together with the *ren*, the individual's name." (Fleming et al., 1980, p. 2).

Classical descriptions are more explicit of the process, but are several millennia removed from the origins of Egyptian mummification. Herodotus' (2009, Bk II, pp. 86–90) Late Period description of Egypt and mummification is the description with which Egyptian mummy researchers are most familiar, including the deluxe treatment with transnasal excerebration and transabdominal evisceration and the lower cost cedar oil and water enema options. The Greek historian, Diodorus Siculus (1933, Bk 1, p. 91), wrote from the Ptolemaic period of three price points similar to those in Herodotus' account, and he provides further detail about the evisceration ritual and process, particularly the universal retention of the heart.

The fate of the viscera is discussed also in the Roman Period descriptions from Plutarch and Porphyry. In two places, Plutarch mentions that viscera were removed from the body and discarded; "the Egyptians, who cut open the dead body and expose it to the sun, and then cast certain parts of it into the river, and perform their offices on the rest of the body, feeling that this part has now at last been made clean" (Plutarch, 1928, p. XVI); and "the Egyptians who extract the viscera of the dead and cut them open in view of the sun, then throw them away as being the cause of every single sin that

the man had committed” (Plutarch, 1957, p. 2,1). Porphyry, regarding an aristocratic burial in his *De Abstinentia*, describes a similar scene in which the entrails were placed in a chest and cast into the Nile to purify the deceased of the sin of eating or drinking something forbidden (Assmann, 2005, p. 83). Assmann (2005, p. 83) has questioned the accuracy and authenticity of this last account, given the “entirely un-Egyptian” act of scapegoating the entrails in judgement of the deceased. Considering Porphyry’s reputation as one of the famous classical vegetarians (see *De Abstinentia ad Esu Animalium*, i.e. *On Abstinence from Eating Food from Animals*), it is also conceivable that he elaborated on Plutarch’s account by adding a dietary morality lesson. Both authors, however, write about casting some portion of the entrails into the Nile, and part of Porphyry’s account bears an unmistakable resemblance to the negative confessions of the *Book of the Dead*. Organ packages and canopic jars have been found to contain incomplete organs (e.g. Brier and Wade, 2001) which, coupled with the importance of protecting embalming remnants from magical use against their owner (Taylor, 2001), may serve to explain this disposal practice.

Evisceration types and features

Transabdominal evisceration was achieved through the creation of a short incision in the left side of the abdomen (Raven and Taconis, 2005). This technique has been considered to be the cause of the transition from flexed to extended burial positions in the 3rd Dynasty, to allow access to the abdomen (Strouhal, 1995). Initially performed as a vertical incision at the level of the hypochondrium (Aufderheide, 2003), it is generally accepted that this feature changed direction and position in the 18th Dynasty to a diagonal, inguinal incision following the iliopubic line (Aufderheide, 2003; Dunand and Lichtenberg, 2006). In exceptional cases, the incision has been made posteriorly in the flank (Dunand and Lichtenberg, 2006; Macke, 2002), although this may be a feature associated with ancient restoration (cf. Aufderheide et al., 2004). Having produced an incision several inches in length, the embalmer was able to remove the intestines, stomach, liver, and lungs. In accordance with its importance as the seat of intelligence and emotion, the heart is said to have been expected to remain within the chest.

The size and shape of the incision have been suggested to be representative of the care with which the embalming was performed; larger, rounded incisions indicating lower quality (Raven and Taconis, 2005). Once the appropriate viscera were removed from the body and the remaining internal treatments were complete, the incision was frequently plugged or covered with linen and/or resin (Raven and Taconis, 2005). In some cases, the lips of the incision were sutured (Iskander, 1980) or a wax or metal plate in the shape of the Left Eye of Horus (*wedjat* or *oudjat*), associated with healing, was placed over the incision (Fleming et al., 1980; Gray, 1967; Raven and Taconis, 2005).

A second category of eviscerated mummies does not exhibit abdominal incisions. Owing to the ambiguous appearance of the access incision’s placement, at the anus, vagina, and/or perineum; to the difficulty inherent in visualising these folded or compressed structures; and to the further complication arising from packing and plugging of these orifices, these three types are considered here as a single group of transperineal eviscerations. Indeed, the act of evisceration through either existing orifice is likely to cause damage to the perineum.

Individuals eviscerated without the abdominal incision are often considered to have undergone the cedar oil (more likely juniper oil and a turpentine-like oleoresin – Raven and Taconis, 2005) enema described by Herodotus (David and Tapp, 1992; Fleming et al., 1980). While the effectiveness of this method has been disputed (Andrews, 1984, p. 17), Ikram’s (2003) experimental mummification of rabbits has shown the efficacy of a turpentine and juniper oil enema in dissolving the viscera and sparing the heart during a forty-day desiccation process. It has also been suggested that anal injection of oleoresin in some cases was intended to preserve the viscera rather than to liquefy them (Taylor, 2001), perhaps similar to the intent of Herodotus’ third method of mummification.

The mummies of the 11th Dynasty queens and princesses of Mentuhotep show no signs of abdominal incision, retain much of their viscera, and exhibit prolapse of the rectum and vagina with associated traces of resin (Aufderheide, 2003). This has led some (e.g. Derry, 1942; Dunand and Lichtenberg, 2006) to suggest that these women had been subjected to an oleoresin treatment. Visceral prolapse, however, may have occurred as a result of gas build-up in the decomposing body that forced

these tissues outwards (Derry, 1942). This is consistent with their incomplete desiccation at burial, implied by the imprints of jewellery on their skin (Aufderheide, 2003), and with similar postmortem pseudo-pathological prolapses in Predynastic mummies (Derry, 1942).

In addition to these questioned examples, numerous natural and anthropogenic mummies were not eviscerated and their internal organs remain in varied states of preservation. When wrapped individually and returned to the body cavity, the organs are largely indistinguishable from one another, and are typically “so thoroughly permeated with the embalming material that their exact identification is generally almost impossible” (Smith and Wood-Jones, 1910, p. 209). Organ packages may be present in the abdominal and thoracic cavities, although without apparent thought to placement in their original position or side (Smith and Wood-Jones, 1910). Similar empty linen rolls may also accompany the wrapped viscera, further confusing identification (Smith and Wood-Jones, 1910).

Large quantities of linen were also frequently placed in the body cavity following evisceration. This linen may be found in the thoracic and abdominal cavities, and may be packed into the abdominal cavity with such force that intact thoracic contents are compacted at the top of the thoracic cavity (Smith and Wood-Jones, 1910). Various other materials, including plants, lichens, feathers, natron, fat, sawdust, and earth, have been included in the body cavities of eviscerated mummies, often cemented together with resin (Harris and Wente, 1980; Iskander and Zaky, 1942). Linen pads and resin were also used to plug and seal the embalming incision, anus, and vagina of the deceased in many cases (Raven and Taconis, 2005). Solid and solidified (once fluid) resinous materials have been included in Egyptian burials since the Predynastic Period, and were likely the product of the conifers and *Pistacia* of Western Asia (Lucas, 1934).

The preceding descriptions represent a summary of the ancient and modern literature on the evisceration features of the Egyptian mummification tradition. Careful examination of this literature suggests that there is considerable variability in body cavity treatment at mummification, and that a closer and more detailed examination is warranted.

Materials and methods

This study employs two samples: (1) a literature review sample of 150 mummies described in the literature and (2) a direct radiological survey sample of 7 mummies' CT scans.

Suitable literature accounts of body cavity treatment were located by English Internet, journal, and PubMed database searches and from references to other English and French sources in the bibliographies of each article located. Popular press articles were not used in spite of the many mummy imaging stories available, as the accounts of mummification from these sources are often inaccurate, insufficient, or highly sensationalised. The exception to this rule was the Berkshire Museum's mummy, Pahat, for which video of the CT scans and reconstructions were available in the online press piece (Berkshire, 2010).

For examples from the scholarly literature to be suitable for this study, the article must have contained individual dating of the remains to dynasty or period, and dating must not have been based on the mummification style alone. Because the state of the literature at present does not allow for dates to be attributed solely on mummification style without the possibility of recursive errors, the mummy must have been dated by inscription analysis, C-14 date, decoration analysis of an original coffin, or the like. Of the examples located, only those that contained explicit, non-conflicting description and/or illustration of the body cavity and organ treatment were used. Mummies were categorised by the presence or absence of evisceration, by the route of evisceration, and by time period. Where available, information on specific organs, packing materials, artefacts, sex, and socio-economic status were also collected for these individuals. Status, in particular, divided the mummies into Elite and Commoner remains, following Kemp's categories of “literate men wielding authority derived from the king, those subordinate to them (doorkeepers, soldiers, quarrymen, and so on)” (Kemp, 1983, p. 81). The “illiterate peasantry” (Kemp, 1983, p. 81), who were considered to fall below the commoners, were not anthropogenically mummified.

The smaller radiological survey sample was drawn from mummies for which original CT data was immediately available. The mummies in this sample include: (1) the New Kingdom mummy RM2718

(Horne and Cardinal, 1995), housed at the Redpath Museum; (2) the 21st Dynasty mummy ROM 910.5.3 (Nelson, 2008a), housed at the Royal Ontario Museum (ROM); (3) the 22nd Dynasty mummy of Djedmaatesankh (Harwood-Nash, 1979; Lewin and Harwood-Nash, 1977; Melcher et al., 1997), also housed at the ROM; (4) the 26th Dynasty mummy of Hetep-Bastet (Nelson, 2008b), housed at the Galerie de l'Université du Québec à Montréal; (5) the Late Period mummy of Pa-Ib (Nelson et al., 2007), housed at the Barnum Museum; (6) the Ptolemaic Period Sulman mummy (Gardner et al., 2004), housed at the Chatham-Kent Museum; and (7) the Roman Period mummy of Lady Hudson (Nelson et al., 2007), housed at the University of Western Ontario. A detailed examination of the torso of each mummy from the original DICOM data was performed using the 64-bit version of Osirix 3.7.1 (www.osirix-viewer.com). Computed tomography provides an ideal means by which to non-destructively examine mummified human remains for the details of evisceration; a three-dimensional view of the interior of the torso, unhampered by the superimposition that is characteristic of plain film radiographs.

Results

Literature findings

Explicit descriptions of evisceration, the details of the route of evisceration, the presence or absence of other evisceration routes, and especially the presence and absence of many organs and packing materials were frequently not reported in the literature sample. Often the basic features of the evisceration had to be inferred from the available information (e.g. implied absence of the intestines and stomach in cases of evisceration where the lungs were explicitly absent). The placement of evisceration incisions, the nature and position of packing materials, and the indications of pre-embalming deterioration of the body (e.g. insects and insect pupae) were very often excluded from descriptions of the mummies. This study obtained sufficient information to closely examine only the presence of evisceration, the transabdominal and transperineal types of evisceration, and the presence of the heart. These features were examined with respect to their frequency (count per period and as a percentage in the entire sample) in time, and by sex and social status where possible.

Direct references with explicit descriptions or depictions of body cavity treatment were identified for 150 mummies (Table 1), including 108 mummies with discernable types of body cavity treatments (Table 2). The descriptions often contained incomplete information on the evisceration route, but were included in the study for their data on evisceration presence, organ presence (Table 3), and packing materials.

The earliest examples of evisceration in this sample come from elites in the Old Kingdom. The data demonstrate an increase, overall and proportionally, in evisceration in the New Kingdom. This increase continued in the Third Intermediate Period, and steady high frequencies existed until the end of the Roman Period (Fig. 1). Evisceration began among males and elites, and does not appear among women in this sample until the New Kingdom, nor among commoners until the Third Intermediate Period.

Transabdominal evisceration was the most frequent form of evisceration (58% of the 108 eviscerations explicitly typed). As in the case of evisceration generally, males and elites predate females and commoners in receiving transabdominal evisceration, although there is insufficient information available to assess temporal trends for sex and status. Explicitly transabdominal evisceration, in this sample however, does not appear until the New Kingdom. Although the elite were being eviscerated in earlier periods (e.g. Queen Hetepheres), detailed evisceration data for mummies prior to the Middle Kingdom are not readily available in the literature, often due to the lack of preserved soft tissue. The lack of available Middle Kingdom studies highlights an important area of future research.

Following transabdominal evisceration in popularity is the absence of evisceration in mummified human remains (24% in this sample). As mentioned above, the earliest mummies were not eviscerated, and this absence is found primarily in females in the early dynastic periods. In this sample, non-eviscerated mummification occurred first among the elite, in keeping with the precedence of their mummification generally.

Table 1

Examples of evisceration in Egyptian mummies drawn from literature review and examined directly.

Source	Name	Dynasty/period	Sex	Status	Eviscerated	Per anum	Perineal	Abdominal
Andelković, 1997	Belgrade mummy	Late/Ptol	M	E	Y			
Aufderheide et al., 2004	1	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	3	Ptol/Rom	M		Y	N	Y	Y
Aufderheide et al., 2004	5	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	6	Ptol/Rom	F		N	/	/	/
Aufderheide et al., 2004	8	Ptol/Rom			N	/	/	/
Aufderheide et al., 2004	10	Ptol/Rom	F		N	/	/	/
Aufderheide et al., 2004	11	Ptol/Rom	F		Y			
Aufderheide et al., 2004	12	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	13	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	15	Ptol/Rom	F		N	/	/	/
Aufderheide et al., 2004	101	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	102	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	104	Ptol/Rom	F		Y			
Aufderheide et al., 2004	106	Ptol/Rom	F		N	/	/	/
Aufderheide et al., 2004	108	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	111	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	112	Ptol/Rom			N	/	/	/
Aufderheide et al., 2004	114	Ptol/Rom	M		Y	N	N	Y
Aufderheide et al., 2004	115	Ptol/Rom	F		Y	N	N	Y
Aufderheide et al., 2004	123	Ptol/Rom	M		Y	N	N	Y
Aufderheide et al., 2004	124	Ptol/Rom	M		Y	N	Y	N
Aufderheide et al., 2004	125	Ptol/Rom	F		Y	N	N	Y
Aufderheide et al., 2004	126	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	128	Ptol/Rom	F		Y	N	N	Y
Aufderheide et al., 2004	129	Ptol/Rom	M		N	/	/	/
Aufderheide et al., 2004	130	Ptol/Rom	M		Y	N	N	Y
Aufderheide et al., 2004	133	Ptol/Rom			Y	N	Y	N
Aufderheide et al., 2004	134	Ptol/Rom	F		Y	N	N	Y
Baldock et al., 1994	Tjentmutengebtiu	22	F	E	Y			Y
Berkshire, 2010	Pahat	Ptolemaic	M	E	Y	N	N	Y

Table 1 (Continued)

Source	Name	Dynasty/period	Sex	Status	Eviscerated	Per anum	Perineal	Abdominal
Bridgman, 1967	Nessihor	Ptol/Rom	M		Y			
Bucaille, 1990; Iskander, 1980	Ramesses II	19	M	E	Y	N	N	Y
Cesarani et al., 2003	Harwa	22/23	M		Y			
Cesarani et al., 2003	Neferrenpet	25/26			Y			
Cesarani et al., 2003	The Bundle	3/4			N	/	/	/
Chan et al., 2008	ANSP 1903.1a	Ptolemaic	F		Y	N	N	Y
Cockburn et al., 1975, 1980; Fleming et al., 1980	PUM II	Ptolemaic	M		Y	N	N	Y
Conlogue, 1999	Cazenovia mummy	Ptol/Rom	F	E	Y	N	N	Y
David and Tapp, 1992	Natsef-amun	21	M	E	Y	N	N	Y
David, 1979	1976.51a	25	F		Y			Y
David, 1979	1777	25	F		Y			
David, 1979	9354	19	M		Y			
David, 1979	5053	25	F		Y			Y
David, 1979	1768	Ptolemaic	M		Y			Y
David, 1979	1770	Ptolemaic	F		Y			
David, 1979	2109	Roman			Y			
David, 1979	1769	Roman			Y			
David, 1979	20,638	Roman	F		Y			
David, 1979	1767	Roman	M		Y			
David, 1979	1766	Roman	F		Y			
David, 1979	1775	Roman	M		Y			
Dawson and Gray, 1968	32,752	Predynastic	F		N	/	/	/
Dawson and Tildesley, 1927	Mummy 24,957	3rd Int	F		Y		N	Y
Dennison, 1999	Tash-pen-khonsu	Ptolemaic	F	E	Y			
Derry, 1942	Setka	5	M	E	Y			
Derry, 1942	unnamed	6	F		N	/	/	/
Derry, 1942	Queen Ashayt	11	F	E	N	/	/	/
Derry, 1942	Princess Mayt	11	F	E	N	/	/	/
Derry, 1942	Princess Kemsit	11	F	E	N	/	/	/
Derry, 1942	Amunet	11	F	E	N	/	/	/
Derry, 1942	Henhenet	11	F		N	/	/	/
Derry, 1942	Woman 23	11	F		N	/	/	/
Derry, 1942	Woman 26	11	F		N	/	/	/
Derry, 1942	Man 24	11	M		N	/	/	/
Derry, 1942	Princess Sitamun	18	F	E	Y			
Derry, 1942	Hatnufer	18	M	E	Y			
Derry, 1942	Siptah	19	M	E	Y			
Derry, 1942	Ramesses IV	20	M	E	Y			
Derry, 1942	Ramesses V	20	M	E	Y			
Derry, 1942	Psusennes I	21	M	E	Y	N	N	Y
Derry, 1942; Bucaille, 1990	Merenptah	19	M	E	Y			Y
Diener, 1986	Bakenren	Late	M	E	Y			Y
Diener, 1986	Child	21			N	/	/	/
Edwards and Shorter, 1938	Mummy 32,751	Predynastic	M		N	/	/	/
Fischer, 2006	Vitrine II	Coptic	F		N	/	/	/
Fischer, 2006	Vitrine I	Coptic	F		N	/	/	/
Fleming et al., 1980	Queen Nodjme	21	F	E	Y			

Table 1 (Continued)

Source	Name	Dynasty/period	Sex	Status	Eviscerated	Per anum	Perineal	Abdominal
Fleming et al., 1980	Bekrenes	26	F		Y			
Foster et al., 1999	Paankhenamun	22	M	C	Y	N	N	Y
Gardner et al., 2004	Sulman Mummy	Ptolemaic	F	C	Y	I	I	I
Getty Museum, 2009	Herakleides	Roman	M		Y			
Gray, 1967	Denon Mummy	26	F		N	/	/	/
Harwood-Nash, 1979	Nakht (ROM I)	20	M	C	N	/	/	/
Iskander, 1980	Ranefer	4/5	M	E	Y			
Iskander, 1980	Karenen	Middle	M		Y			
Iskander, 1980	Tutankhamun	18	M	E	Y	N	N	Y
Kieser et al., 2004	Otago Mummy	30	F	C	Y	N	N	Y
Kircos and Teeter, 1991	Petosisiris	26	F		Y	N	N	Y
Knudsen, 2001	Tamat	3rd Int	F	E	Y			
Kristen and Reyman, 1980	DIA I/II	19	M		Y			
Lombardi, 1999	Nefer Atethu	3rd Int	F		Y	N	N	Y
Macleod et al., 2000	1911-210-1	Roman	M	E	Y			
Melcher et al., 1997	Djedmaatesankh	22	F	C	Y	N	N	Y
Merigaud, 2007	Seramon	21	M	E	Y	N	N	Y
Merigaud, 2007	Ankhpakhered	26	M	E	Y			
Michael C Carlos Museum, 2002	Ramesses I	19	M	E	Y	N	N	Y
Miller, 2004; David, 1979	Child Mummy 9319	Roman			Y			
Mininberg, 2001	Nesi-amin	25	M		Y			
Mininberg, 2001	Esmin	Ptolemaic	M		Y			
Nelson et al., 2007	Pa-Ib	26	F	C	Y	N	N	Y
Nelson et al., 2007	Lady Hudson	Roman	F	E	Y	I	I	I
Nelson, 2008a	ROM 910.5.3	21	F		Y	N	Y	N
Nelson, 2008b	Hetep-Bastet	26	F	C	Y	N	N	Y
Notman et al., 1986	Nameless Priest	18	M	E	Y			
Notman, 1986	Lady Tashat	25	F	C	Y			
Pahl, 1986	Mummy 2569	Late	F		Y			Y
Pahl, 1986	Mummy 326	Late	M		Y			Y
Pickering et al., 1990	Wenuhotep	Late	F	E	Y	N	N	Y
Promińska, 1986	Mummy 1	Coptic	M		N	/	/	/
Promińska, 1986	Mummy 2	Coptic	M		N	/	/	/
Promińska, 1986	Mummy 3	Coptic	M		N	/	/	/
Raven and Taconis, 2005	1	3rd Int	M		Y			Y
Raven and Taconis, 2005	2	3rd Int	F		Y	Y		N
Raven and Taconis, 2005	3	3rd Int	M		Y			N
Raven and Taconis, 2005	4	3rd Int	F		Y			Y
Raven and Taconis, 2005	5	3rd Int	F		Y			Y
Raven and Taconis, 2005	6	3rd Int	F		Y			Y

Table 1 (Continued)

Source	Name	Dynasty/period	Sex	Status	Eviscerated	Per anum	Perineal	Abdominal
Raven and Taconis, 2005	7	3rd Int	M	C	Y			Y
Raven and Taconis, 2005	8	3rd Int	M		Y			Y
Raven and Taconis, 2005	9	Late	M	C	Y			Y
Raven and Taconis, 2005	10	Late	M	E	Y			Y
Raven and Taconis, 2005	11	Late	M		Y			Y
Raven and Taconis, 2005	12	Late	M	C	Y			Y
Raven and Taconis, 2005	14	Late	F	E	Y			Y
Raven and Taconis, 2005	15	Late	M		Y			Y
Raven and Taconis, 2005	16	Late	M	E	Y			Y
Raven and Taconis, 2005	17	Late	M	E	Y	Y		N
Raven and Taconis, 2005	18	Late	M		Y			N
Raven and Taconis, 2005	19	Late	M		Y			Y
Raven and Taconis, 2005	20	Ptolemaic	F		Y			Y
Raven and Taconis, 2005	21	Ptolemaic	M		Y			Y
Raven and Taconis, 2005	23	Ptolemaic			Y			N
Raven and Taconis, 2005	24	Roman	M		Y			N
Raven and Taconis, 2005	25	Roman			Y			N
Raven and Taconis, 2005	26	Roman	F		Y			Y
Raven and Taconis, 2005	27	Roman	M		Y			Y
Raven and Taconis, 2005	28	Roman	M		Y			N
Raven and Taconis, 2005	29	Roman	M		Y			Y
Raven and Taconis, 2005	30	Roman	M		Y			Y
Raven and Taconis, 2005	31	Roman	M		Y			Y
Reyman and Peck, 1980	PUM III	22	F		Y	Y		N
Reyman and Peck, 1980	PUM IV	Roman	M		Y	Y		N
Rühli and Böni, 2000a,b	Winterthur Mummy	Ptolemaic	M		Y	N	N	Y
Rühli and Böni, 2000a, Rühli et al., 2004	Nakht (Neuchatel)	21	M		Y			Y
Sigmund and Minas, 2002	Paestjauemauinu	25/26	F	E	Y	N	Y	Y
Taylor, 1995	Horemkenesi	21	M	E	Y	N	N	Y

Table 1 (Continued)

Source	Name	Dynasty/period	Sex	Status	Eviscerated	Per anum	Perineal	Abdominal
Teeter and Vannier, 2009; Bonn-Muller, 2009; Teeter, 2009 (in Teeter and Johnson, 2009)	Meresamun	22/23	F	E	Y	N	N	Y
Vancouver Museum, 2004	Panechates	Roman	M		Y	N	N	Y
Watson and Myers, 1993	Baketenhernakht	22	F	E	Y	N	N	Y

Table 2
Summary of evisceration findings.

Total sample	Eviscerated	Intact	Transabdominal evisceration	Transperineal evisceration	Indeterminate technique
150	114	36	63	9	44

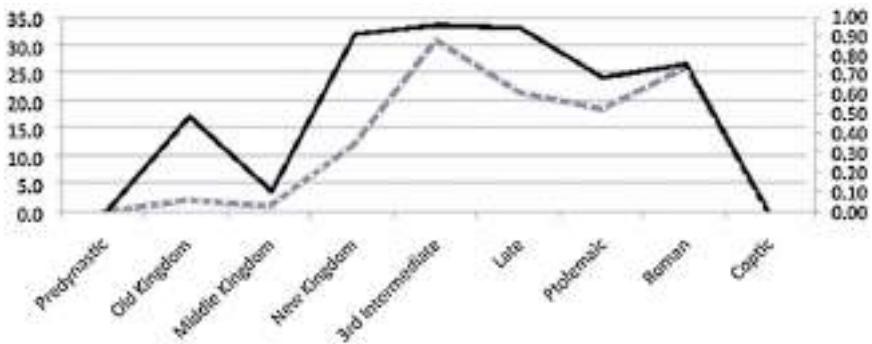


Fig. 1. Graph showing the count and fractional frequencies of evisceration (grey dotted line, scale left – count; black line, scale right – fraction) by time period. Examples with dates across one or more time period were divided equally between both periods.

The transperineal forms of evisceration, including per anum evisceration, were rarely applied to individuals in this sample (approximately 8% of typed eviscerations). Both per anum evisceration, specifically, and transperineal evisceration, generally, began among elites of the Third Intermediate Period and remained an elite practice throughout its use.

Transabdominal incisions for the purpose of evisceration were, on average, about 110 mm in length and typically ranged from 100 to 120 mm. This accords well with the average of 100 mm from the data gathered by [Smith and Wood-Jones \(1910\)](#) for Nubian mummies. Overwhelmingly, the incisions were made in the left flank, and only in a single case in the literature was the incision recorded for the right side ([Smith and Wood-Jones, 1910](#)). The transition from a vertical, hypochondrial incision to a diagonal, inguinal one occurs in the New Kingdom, but both forms persist into the Roman Period in both status groups. Use of an incision plate to cover or seal the incision was an uncommon feature (9 cases of 43 explicitly noted). Its use began among elite New Kingdom males, in this sample, and after its use spread to commoners and females in the Third Intermediate Period, it declined to absence following the Late Period.

Among the eviscerated mummies, the heart was noted as intact in only 21 of the 80 individuals where this organ's disposition was recorded ([Table 3](#)). The heart was noted as intact, and specifically in elites, as early as the Middle Kingdom, in this sample. The only eviscerated mummies in the Middle

Table 3

Disposition of internal organs in Egyptian mummies drawn from literature review and examined directly.

Source	Name	Heart intact	Heart replaced	Lungs intact	Stomach intact	Intestine intact	Liver intact	Kidneys intact
Andelković, 1997	Belgrade mummy	Y	/	N	N	N	N	
Aufderheide et al., 2004	1	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	3	N	N	Y				N
Aufderheide et al., 2004	5	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	6	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	8	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	10	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	11	N	N	N	N	N	N	N
Aufderheide et al., 2004	12	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	13	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	15	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	101	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	102	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	104	N	N	N	N	N	N	N
Aufderheide et al., 2004	106	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	108	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	111	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	112	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	114	N	N	N	N	N	N	N
Aufderheide et al., 2004	115	N	N	N	N	N	N	N
Aufderheide et al., 2004	123	N	N	N	N	N	N	N
Aufderheide et al., 2004	124	N	N	N	N	N	N	N
Aufderheide et al., 2004	125	N	N	N	N	N	N	N
Aufderheide et al., 2004	126	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	128	N	N	N	N	N	N	N
Aufderheide et al., 2004	129	Y	/	Y	Y	Y	Y	Y
Aufderheide et al., 2004	130	N	N	N	N	N	N	N
Aufderheide et al., 2004	133	N	N	N	N	N	N	N
Aufderheide et al., 2004	134	N	N	N	N	N	N	N

Table 3 (Continued)

Source	Name	Heart intact	Heart replaced	Lungs intact	Stomach intact	Intestine intact	Liver intact	Kidneys intact
Baldock et al., 1994	Tjentmutengebtu	Y	/	N	N	N	N	
Berkshire, 2010	Pahat			N	N	N	N	
Bridgman, 1967	Nessihor				N	N	N	
Bucaille, 1990;	Ramesses II							
Iskander, 1980								
Cesarani et al., 2003	Harwa							
Cesarani et al., 2003	Neferrenpet							
Cesarani et al., 2003	The Bundle	Y	/	Y	Y	Y	Y	Y
Chan et al., 2008	ANSP 1903.1a	Y	/	N	N	N	N	
Cockburn et al., 1975, 1980;	PUM II	N	N	N	N	N	N	N
Fleming et al., 1980								
Conlogue, 1999	Cazenovia mummy							
David and Tapp, 1992	Natsef-amun	N		N	N	N	N	N
David, 1979	1976.51a	N	N	N				
David, 1979	1777	N	N	Y				N
David, 1979	9354	Y	/	Y	N	N	N	
David, 1979	5053	N	N	N	N	N	N	
David, 1979	1768	N	N	N				
David, 1979	1770	N	N	N	N	N	N	
David, 1979	2109	N	N	N	N	N	N	
David, 1979	1769	N	N	Y	N	N	N	
David, 1979	20,638	N	N		N	N	N	
David, 1979	1767	N	N	N	N	N	N	
David, 1979	1766	N	N	Y (right)	N	N	N	
David, 1979	1775				N	N	N	
Dawson and Gray, 1968	32,752	Y	/	Y	Y	Y	Y	Y
Dawson and Tildesley, 1927	Mummy 24,957	Y	/					
Dennison, 1999	Tash-pen-khonsu	Y	/	Y				
Derry, 1942	Setka							
Derry, 1942	Unnamed	Y	/	Y	Y	Y	Y	Y
Derry, 1942	Queen Ashayt	Y	/	Y	Y	Y	Y	Y
Derry, 1942	Princess Mayt	Y	/	Y	Y	Y	Y	Y
Derry, 1942	Princess Kemsit	Y	/	Y	Y	Y	Y	Y
Derry, 1942	Amunet	Y	/	Y	Y	Y	Y	Y
Derry, 1942	Henhenet	Y	/	Y	Y	Y	Y	Y
Derry, 1942	Woman 23	Y	/	Y	Y	Y	Y	Y
Derry, 1942	Woman 26	Y	/	Y	Y	Y	Y	Y
Derry, 1942	Man 24	Y	/	Y	Y	Y	Y	Y
Derry, 1942	Princess Sitamun							
Derry, 1942	Hatnufer			Y				
Derry, 1942	Siptah							
Derry, 1942	Ramesses IV							
Derry, 1942	Ramesses V							
Derry, 1942	Psusennes I							
Derry, 1942;	Merenptah							
Bucaille, 1990								
Diener, 1986	Bakenren							
Diener, 1986	Child	Y	/	Y	Y	Y	Y	Y
Edwards and Shorter, 1938	Mummy 32,751	Y	/	Y	Y	Y	Y	Y
Fischer, 2006	Vitrine II	Y	/	Y	Y	Y	Y	Y

Table 3 (Continued)

Source	Name	Heart intact	Heart replaced	Lungs intact	Stomach intact	Intestine intact	Liver intact	Kidneys intact
Fischer, 2006	Vitrine I	Y	/	Y	Y	Y	Y	Y
Fleming et al., 1980	Queen Nodjme							
Fleming et al., 1980	Bekrenes							
Foster et al., 1999	Paankhenamun	N	N	N	N	N	N	N
Gardner et al., 2004	Sulman Mummy	I	I	I	I	I	I	I
Getty Museum, 2009	Herakleides	N	N	Y	N	N	N	
Gray, 1967	Denon Mummy	Y	/	Y	Y	Y	Y	Y
Harwood-Nash, 1979	Nakht (ROM I)	Y	/	Y	Y	Y	Y	Y
Iskander, 1980	Ranefer							
Iskander, 1980	Karenen	Y	/	N	N	N	N	
Iskander, 1980	Tutankhamun				N	N	N	
Kieser et al., 2004	Otago Mummy	N	N	N	N	N	N	
Kircos and Teeter, 1991	Petosiris							
Knudsen, 2001	Tamat	Y		Y				Y
Kristen and Reyman, 1980	DIA I/II	N	Y					
Lombardi, 1999	Nefer Atethu	Y	/	N	N	N	N	
Macleod et al., 2000	1911-210-1			N	N	N	N	
Melcher et al., 1997	Djedmaatesankh	N	N	N	N	N	N	N
Merigaud, 2007	Seramon	N	N	N	N	N	N	N
Merigaud, 2007	Ankhpakhered	N		N	N	N	N	N
Michael C Carlos Museum, 2002	Ramesses I	Y	/	N	N	N	N	
Miller, 2004; David, 1979	Child Mummy 9319	N	N	Y				
Mininberg, 2001	Nesi-amin							
Mininberg, 2001	Esmin							
Nelson et al., 2007	Pa-Ib	N	N	N	N	N	N	N
Nelson et al., 2007	Lady Hudson	I	I	I	I	I	I	I
Nelson, 2008a	ROM 910.5.3	N	N	N	N	N	N	N
Nelson, 2008b	Hetep-Bastet	I	I	I	N	N	N	I
Notman et al., 1986	Nameless Priest	Y	/	N	N	N	N	
Notman, 1986	Lady Tashat	Y	/					
Pahl, 1986	Mummy 2569							
Pahl, 1986	Mummy 326							
Pickering et al., 1990	Wenuhotep	N	N	N	N	N	N	Y
Promińska, 1986	Mummy 1	Y	/	Y	Y	Y	Y	Y
Promińska, 1986	Mummy 2	Y	/	Y	Y	Y	Y	Y
Promińska, 1986	Mummy 3	Y	/	Y	Y	Y	Y	Y
Raven and Taconis, 2005	1	N	N	N	N	N	N	N
Raven and Taconis, 2005	2	N	N	N	N	N	N	N
Raven and Taconis, 2005	3	N	N	N	N	N	N	N
Raven and Taconis, 2005	4				N	N	N	
Raven and Taconis, 2005	5				N	N	N	

Table 3 (Continued)

Source	Name	Heart intact	Heart replaced	Lungs intact	Stomach intact	Intestine intact	Liver intact	Kidneys intact
Raven and Taconis, 2005	6	N	N	N	N	N	N	
Raven and Taconis, 2005	7	N	N	N	N	N	N	N
Raven and Taconis, 2005	8	N	N	N	N	N	N	N
Raven and Taconis, 2005	9				N	N	N	
Raven and Taconis, 2005	10	N	N	N	N	N	N	N
Raven and Taconis, 2005	11	Y	/		N	N	N	N
Raven and Taconis, 2005	12	Y	/		N	N	N	
Raven and Taconis, 2005	14	Y	/		N	N	N	N
Raven and Taconis, 2005	15	Y	/		N	N	N	
Raven and Taconis, 2005	16	Y	/	N	N	N	N	N
Raven and Taconis, 2005	17	N	N	N	N	N	N	N
Raven and Taconis, 2005	18	N	N	N	N	N	N	N
Raven and Taconis, 2005	19	Y	/		N	N	N	
Raven and Taconis, 2005	20	N	N	N	N	N	N	
Raven and Taconis, 2005	21	N	N	N	N	N	N	N
Raven and Taconis, 2005	23	N	N	N	N	N	N	N
Raven and Taconis, 2005	24	N	N	N	N	N	N	N
Raven and Taconis, 2005	25	N	N	N	N	N	N	N
Raven and Taconis, 2005	26	Y	/	N	N	N	N	
Raven and Taconis, 2005	27	N	N	N	N	N	N	N
Raven and Taconis, 2005	28	N	N	N	N	N	N	N
Raven and Taconis, 2005	29	N	N	N	N	N	N	N
Raven and Taconis, 2005	30	N	N	N	N	N	N	N
Raven and Taconis, 2005	31	N	N	N	N	N	N	N
Reyman and Peck, 1980	PUM III	Y	/	Y	N	N	Y	N
Reyman and Peck, 1980	PUM IV	N	N	N	N	N	N	
Rühli and Böni, 2000a,b	Winterthur Mummy			N	N	N	N	
Rühli and Böni, 2000a, Rühli et al., 2004	Nakht (Neuchatel)							
Sigmund and Minas, 2002	Paestjauemaunu	N	N	N	N	N	N	N
Taylor, 1995	Horemkenesi	N	N	N	N	N	N	

Table 3 (Continued)

Source	Name	Heart intact	Heart replaced	Lungs intact	Stomach intact	Intestine intact	Liver intact	Kidneys intact
Teeter and Vannier, 2009; Bonn-Muller, 2009; Teeter, 2009 (in Teeter and Johnson, 2009)	Meresamun	N	N	N	N	N	N	
Vancouver Museum, 2004	Panechates	N	N	N	N	N	N	
Watson and Myers, 1993	Baketenhernakht	Y	/	N	N	N	N	

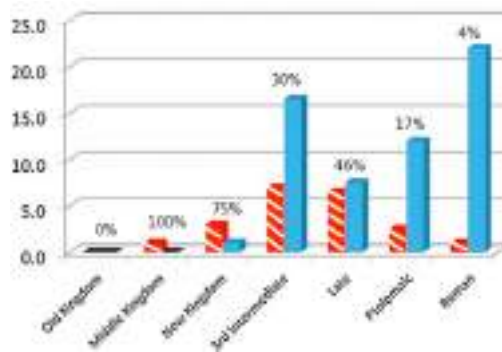


Fig. 2. Graph showing the frequencies of evisceration with heart retention (red, striped) and of evisceration with heart absence (blue, solid). Heart retention is also noted as a percentage of total heart descriptions. Examples with dates across one or more time period were divided equally between both periods. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Kingdom, whose heart status was noted and whose hearts were intact, were males. Consequently, male retention and absence of the heart preceded female heart retention and absence, respectively. The frequency of evisceration-related heart retention increased over time, peaking in the Third Intermediate and Late Periods, with a subsequent decline in the Ptolemaic and Roman Periods. However, the frequency of heart retention saw a general decrease, with a small resurgence in the Late Period (Fig. 2).

There were insufficient data to examine trends in the disposition of other organs, but five individuals stand out in relation to organ treatment. Four individuals, including both males and females, dating from the Third Intermediate to Roman Periods were noted as absent their hearts but retaining their lungs. One other individual, a woman in the Third Intermediate Period had only her stomach, intestines, and kidneys removed. Of those nine individuals eviscerated by the perineal route, there were two cases of intact hearts, two of intact lungs (one coinciding with an intact heart), and two (possibly) intact livers. One transperineally eviscerated individual, an elite female in the Third Intermediate or Late Period, was associated with a packaged organ (lung). Otherwise, no cases of returned or preserved (insufficient data on canopic jar association) organs were noted in perineal/per anum/per vaginum eviscerations.

Packing of the body cavity was common from the Old Kingdom onward, and most commonly consisted of linen and resin. Plant material and sawdust were introduced to the body cavity intermittently from the New Kingdom onward, and soil packing was present in both sexes and statuses beginning in the Third Intermediate Period. The use of natron and fat was limited to a single elite New Kingdom male. Anal and perineal tampons were present in members of both sexes and statuses (14 of

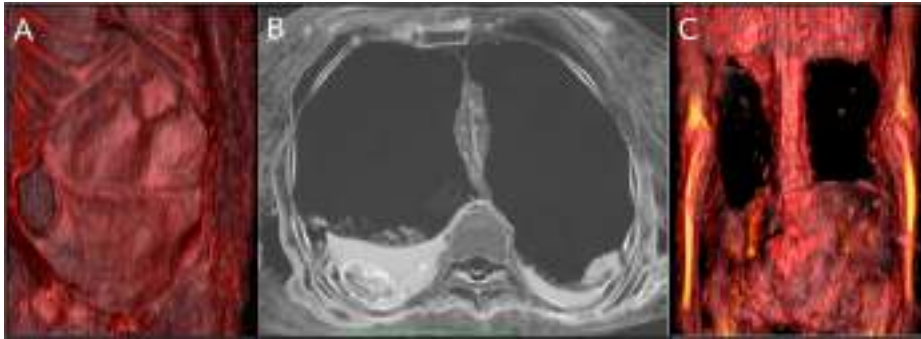


Fig. 3. CT scan and reconstructions of RM-2718, showing (A) the left transabdominal evisceration incision viewed from inside the body cavity; (B) the intact heart, possible organ package, and solidified straight level of resin; and (C) damage to the posterior of the mummy (note the straight cuts above, below, and along the midline).

37) from the Third Intermediate Period onwards. In only one case was there an anal/perineal tampon present when evisceration (of either type) was not performed.

Mummification artefacts (e.g. scarabs, beads, or statuettes) do not appear in this sample until the Third Intermediate Period, and are present in both sexes. All cases in which mortuary artefacts were present in or on the bodies were elite individuals. Both elites and commoners were having organs preserved and replaced in the body cavity by the Third Intermediate Period, but, while the mummification artefacts consisted largely of statuettes, not all of the statuettes were of the typical Sons of Horus variety.

Radiological findings

RM2718

This individual has been eviscerated by way of a vertical, hypochondrial 80 mm incision on the left side (Fig. 3A). The heart is present, much reduced in size, in its pericardial sac (Fig. 3B). The lungs, intestines, stomach, and liver are not intact in the body cavity. The diaphragm has been largely excised. This individual was opened, likely in modern times, along the back, resulting in damage to posterior structures from the sacrum to the level of T9 (Fig. 3C). The kidneys may have been removed during embalming or been destroyed by this damage. There is one package of heterogeneous radiodensity (–230 to 660 HU) in the right thoracic cavity, running vertically from the level of T6 to T9 (Fig. 3B). There is a remnant of a second heterogeneously radiodense (–140 to 570 HU) package, interrupted by the damage to the back, at the level of T10 and T11. Hardened resin is present in the dependent fifth of the thoracic cavity (Fig. 3B), more so on the right than the left. Below the inferior border of the damage, there is a small amount of resin on the pelvis. Neither sutures nor an incision plate nor an anal tampon are present in this individual.

Djedmaatesankh

This individual has been eviscerated by way of a diagonal, inguinal 130 mm incision on the left side (Fig. 4A). The heart, lungs, intestines, liver, stomach, and kidneys are not intact in the body cavity. The diaphragm has been excised. Five packages of heterogeneous radiodensity (ranging from –300 to 250 HU) have been placed in the body cavity (Fig. 4B), which may represent packaged organs.

Package 1 – Right thoracic cavity (T5–T9), 30–150 HU

Package 2 – Left thoracic cavity (T6–L2), 90–200 HU

Package 3 – Crossing midline thoracic/abdominal cavity (T9–L4), –100 to 200 HU

Package 4 – Left abdominal cavity (T11–L4), –100 to 100 HU

Package 5 – Central abdominal cavity (T12–L5), –300 to 250 HU

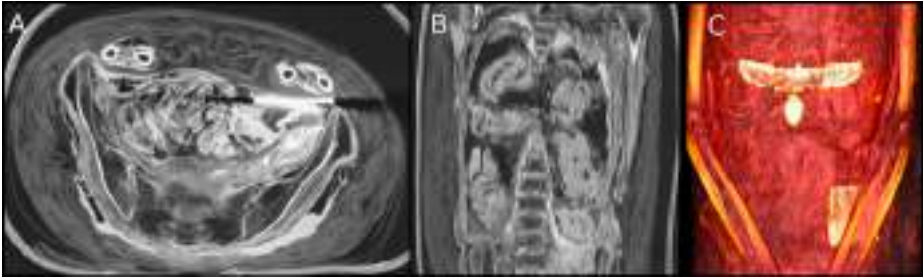


Fig. 4. CT scan and reconstruction of Djedmaatesankh, showing (A) the abdominal packing and the transabdominal incision beneath the incision plate; (B) the possible organ packages throughout the body cavity; and (C) the incision plate, scarab, and pectoral.

Additional linen padding is present in the lower abdomen (Fig. 4A) and resin has formed hardened pools from the level of T9 to L2 on the right and T9 to L5 on the left. There is possibly a vaginal tampon but no apparent anal tampon, and resin is apparent at the anus. The evisceration incision has not been sutured, but has been covered by about 5 mm thick, high-density plate (2039+HU, likely metal) measuring 67 mm by 80 mm (Fig. 4C). A scarab has been placed external to the body cavity (Fig. 4C), in the wrappings at the midline L1/L2 level, immediately inferior to a falcon (or winged scarab, sun disc, or uraeus) pectoral (Fig. 4C). No inscriptions are apparent on the scarab at this resolution (0.49 mm × 0.49 mm × 3.0 mm). Another small amulet (Djed pillar?) is present beneath the outermost layer of wrapping on the left at the same level as the scarab.

Lady Hudson

The chest and upper abdomen are not preserved in this mummy (Fig. 5A). However, in the lower abdomen, at the level of the pelvis, linen packing with resin density inclusions is present in this individual (Fig. 5A and B). The resin is present on the left side of the packing only (Fig. 5B), and may be related to an inguinal transabdominal evisceration incision, similar to that in Djedmaatesankh (Fig. 4A). The heart, lungs, intestines, liver, stomach, and kidneys are not intact in the body cavity and could not be assessed. The diaphragm could not be assessed due to the damage to the chest and abdomen. Anal and vaginal tampons were also not assessed due to the condition of this mummy.

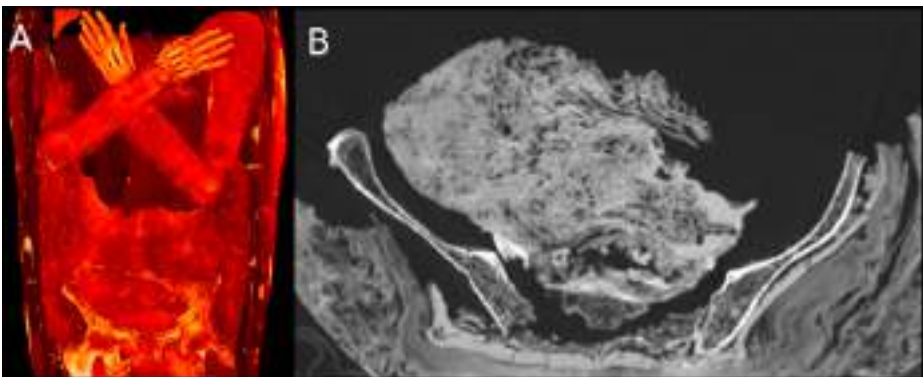


Fig. 5. CT scan and reconstruction of Lady Hudson, showing (A) the pelvic packing and damaged thorax (note the coffin boards visible beneath the thoracic cavity); and (B) the linen packing in the pelvis with the small pool of resin on it hinting at a transabdominal evisceration.

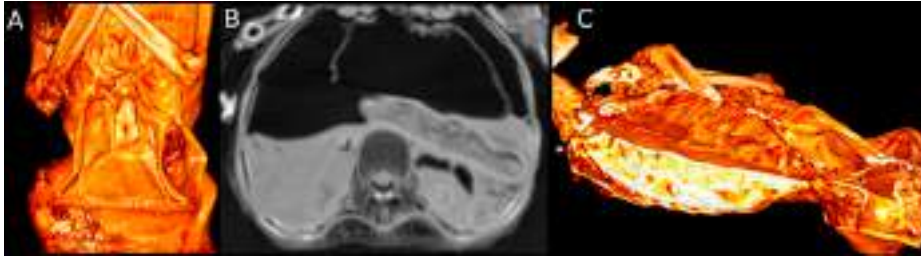


Fig. 6. CT scan and reconstructions of Pa-1b, showing (A) the transabdominal evisceration incision without sutures or incision plate; (B) the linear diaphragm remnants and possible organ packages (#3 and #5); (C) and a cross-sectional view of the solidified straight level of resin with package #5 sticking out.

Pa-1b

This individual has been eviscerated by way of a vertical, hypochondrial 110 mm incision on the left side (Fig. 6A). The heart, lungs, intestines, liver, stomach, and kidneys are not intact in the body cavity. The diaphragm has been incised, and remnants are present in the thoracic cavity (Fig. 6B). Five packages of rolled linen, impregnated with resin and containing numerous small voids, have been placed in the body cavity (Fig. 6B and C).

Package 1 – Left thoracic cavity (T3–T10)

Package 2 – Left thoracic cavity (T6–T12)

Package 3 – Left thoracic/abdominal cavity, medially (T10–L1)

Package 4 – Left abdominal cavity (T12–L3)

Package 5 – Crossing midline thoracic/abdominal cavity (T9–L1)

Most or all of these packages may consist only of rolled linen and resin, and likely do not contain preserved organs. An additional linen pad is located in the right thoracic cavity between the T6 and T9 levels, and more linen packing is present in the lower abdomen. A large amount of hardened resin is present in the dependent portion of the body cavity and fills between one third and one half of the body cavity from the throat to the bottom of the abdomen (Fig. 6C). The evisceration incision has neither sutures nor an incision plate (Fig. 6A). The anus may contain a linen tampon, given the lack of resin leakage from this orifice.

Hetep-Bastet

This individual has been eviscerated by way of a vertical, hypochondrial 80 mm incision on the left side (Fig. 7A). Due to damage in modern times (Nelson, 2008b), the chest cavity is a jumbled, fragmented mass of ribs, vertebrae, resin, and skin (Fig. 7B). Although the thoracic structures could not be assessed for this individual, the stomach, liver, and intestines are not intact in the abdominal cavity. The diaphragm could not be assessed due to the damage. No packages are present in either the damaged thoracic cavity or the intact abdominal cavity, nor are they present between the thighs. Rather

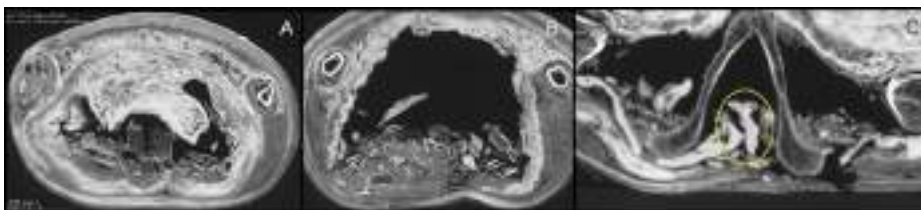


Fig. 7. CT scan of Hetep-Bastet, showing (A) the large quantity of external abdominal packing entering through the transabdominal evisceration incision which lacks sutures and incision plate; (B) the jumbled contents of the thoracic cavity; and (C) the resin-impregnated anal tampon (indicated).



Fig. 8. CT scan and reconstructions of ROM 910.5.3, showing (A) the large transperineal evisceration orifice; (B) the great vessel remnants in the incised pericardial sac; and (C) a cropped view showing the insect remains (indicated) and the possible pancreas fragment with diaphragm remnants visualised as a dark shadow above it.

than packing the body cavity internally, a large amount of resin-impregnated linen is present outside the abdomen, compressing the anterior abdominal wall against the spine (Fig. 7A). The presence of a vaginal tampon is uncertain, but an anal tampon of resin-impregnated linen is apparent (Fig. 7C). No sutures or incision plate are present at this individual's evisceration incision (Fig. 7A).

ROM 910.5.3

This individual has been eviscerated, but lacks the abdominal incision, and evisceration was performed through the large artificial orifice running from the vagina to the anus (Fig. 8A). The heart is absent, but the great vessels remain as a high-density mass in the pericardial sac (Fig. 8B). The lungs, intestines, stomach, liver, and kidneys are not intact in the body cavity, but a radiodense portion of the pancreas may be present (Fig. 8C). The diaphragm has been incised and remnants are appreciable in the thoracic cavity (Fig. 8C). There are no packages, packing material, or artefacts in this mummy. The vaginal and anal ends of the perineal hole each contain a resin density tampon. In the dependent portion of the body cavity, numerous small ovoid objects, favoured to be fly pupae and/or larvae, are present (Fig. 8C).

Sulman mummy

This individual has been wrapped or rewrapped in an advanced state of decomposition (Fig. 9A), and the method of evisceration is unclear. The heart, lungs, stomach, liver, and kidneys are not intact in the body cavity. In the lower abdomen, however, possible loops of faeces-filled small bowel are visualised (Fig. 9B). The diaphragm has been affected by the decomposition and handling, but likely remnants imply its incision rather than removal. A thin layer of resin is present in the thoracic cavity,

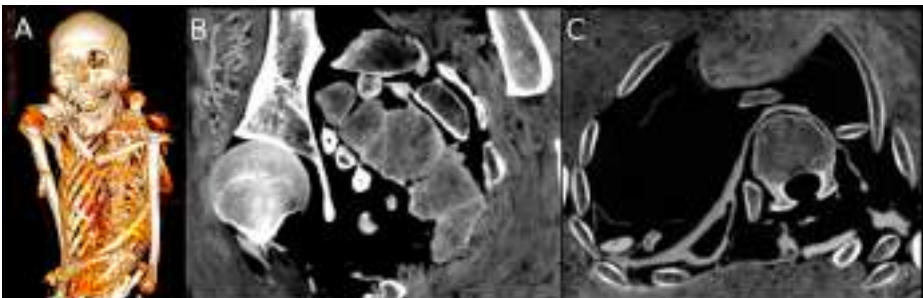


Fig. 9. CT scan and reconstruction of the Sulman mummy, showing (A) indications of rewrapping (the dislocations of the forearms and clavicle from their anatomical positions, the loose metacarpal in the outer wrappings, and the 3 curled fingers of the right hand still on the left shoulder despite the extended position of the arms); (B) the remnant bowel loops; and (C) the layer of resin adherent to the pleura.

adherent to remnants of the pleura (Fig. 9C). There are no packages present in the body cavity or between the thighs, and there are no apparent anal or vaginal tampons.

Discussion

Evisceration has been an important feature of Egyptian anthropogenic mummification since its inception in the early Old Kingdom. The sex and status distributions of eviscerations noted here are in agreement with Strouhal (1995) observation that new mummification features, like all new advantages, were first the privilege of the pharaoh, then increasingly permissible to progressively lower social classes. Evisceration began with the pharaoh, progressed to the men and women of the royal family and nobility, and eventually trickled down to the middle class. The increase in frequency from the New Kingdom and Third Intermediate Period (Fig. 1), as well as the inclusion of the non-pharaonic groups, coincides with the timing of the democratisation of mummification in the New Kingdom (cf. Aufderheide, 2003). Transabdominal evisceration, the overwhelming majority of eviscerations, also follows this specific trend, with male elites predated the females and commoners receiving this form of evisceration.

The historical transition from the use of a vertical, hypochondrial incision to a diagonal, inguinal one for transabdominal evisceration was not the complete transition implied by the literature (e.g. Aufderheide, 2003; Dunand and Lichtenberg, 2006; Raven and Taconis, 2005), and both diagonal/inguinal and vertical/hypochondrial incisions were present until the decline of mummification following the Roman Period. The direction of the incision persistently corresponded to the position. The length of the incision was also persistently in the range of 80–130 mm. The experimental mummification performed by Brier and Wade (2001) provides the figure of 3 inches (76 mm) as an approximate minimum length for removal of the largest internal organ - the liver. Even at 3 inches in length (~45 mm diameter), removal of the liver required substantial manipulation and “was delivered through the incision a lobe at a time” (Brier and Wade, 2001, p. 122).

Given the degree of variation (even minor ones) that occurs throughout Egyptian mummification over three millennia, and given the variation in direction and level at which the incisions were made, it is curious that the placement side did not change. This persistence most likely has its roots in the relative stasis of anatomy, rather than in the changing ideology of mummification. An incision on the left side of the abdomen, hypochondrial or inguinal, provides immediate access to the intestines and, following their removal, provides sufficient working space and access to the arteries and ligaments securing the liver. An approach from the right side would result in a most awkward attempt to cleanly excise the liver one-handed through an 80 mm hole.

Interestingly, the transperineal forms of evisceration appear relatively late (Third Intermediate Period – first of nine cases) and do not first occur in male elites. The commoners being eviscerated were not prepared using this evisceration procedure, receiving transabdominal eviscerations instead. Prior to the Third Intermediate Period, few women who were mummified were eviscerated, and it is in this group that transperineal evisceration begins. Transperineal evisceration was rarely applied in this sample and it is not clear why this form would not follow the trend seen in transabdominal evisceration and in excerebration (Wade et al., 2011).

One possible explanation for this different trend is that the method presented itself as an option and did so more readily in the female anatomy. The pseudo-prolapse at the anus and vagina together, particularly among noble females purportedly delayed for several days to deter necrophiles (Herodotus, 2009), may have been quite pronounced and offered an obvious means by which to remove the viscera. Either in concert with this phenomenon, or for its own sake, the option to remove the viscera without producing any unnecessary new holes may have appealed to the embalmers. Regardless of the reason for the introduction of perineal forms of evisceration, their application begins and remains among the elite. Perineal removal of the viscera, whether manually or by cedar oil enema, does not appear in the commoners of this sample, and should not be considered a second-rate option for evisceration following Herodotus.

No clear evidence of evisceration by chemical means; that is, by oleoresin enema, was noted in the mummies of this study. It is possible, though unlikely given that uneviscerated mummies remain preserved, that the turpentine enema method resulted in a poorly preserved mummy and, regardless

of the numbers in which they were produced, they have failed to survive to be recorded in the present. However, embalmers likely received plentiful feedback on their work (i.e. family visits to tombs, tomb robbery restorations, and relocation of royal tombs), and it is even less likely that an especially poor or temporary embalming method would have persisted for long. If chemical evisceration was occurring, then it might be expected to spare the heart (Ikram, 2003) and lungs, with only the abdominal contents (“the whole stomach and intestines” as Herodotus notes) being dissolved. In the transperineal eviscerations in this sample, there are single individuals with the heart or lungs intact and another with both intact. However, the possibly intact livers of two individuals and the packaged lung of another transperineal evisceration shed doubt on this mechanism.

Once the body cavity was accessed by either the perineal or abdominal route, there remained the question of which organs were appropriate to remove and to preserve. The central assumption implicit in the literature is that the initial motive for removing the organs was to spare the rest of the body from the decay the organs would promote; that is, that the early mummification attempts were devoted to preserving the form rather than the substance of the body. However, it is possible that at least some of the organs were being removed specifically to preserve them in addition to the body. Certainly, the Egyptians were well aware of the necessity of gutting fish and animals to preserve the meat, but one of the earliest indicators of evisceration is the presence of niches or jars for viscera (D’Auria et al., 1992; Dunand and Lichtenberg, 2006); largely the same set of viscera that were preserved throughout Egyptian evisceration’s history.

Although there is the suggestion of substantial variation in the association of particular organs with particular deities, in the later Sons of Horus canopic jars and statuettes (Taylor, 2001), the same set of organs are typically of interest to the embalmers; the lungs, liver, stomach, and intestines. Taylor (2001) also notes that, while the rationale for selecting these organs is not well understood, it is likely not a coincidence that those associated with digestion (stomach and intestines) were chosen. The digestive tracts of some eviscerated mummified ibises have also been found returned to the body cavity with their last meals intact (Wade et al., 2012). That the lungs were obviously (even to the anatomically gifted but physiologically challenged knowledge of the Egyptian embalmer) the organs of breath makes their choice equally logical. The rationale for the choice of the liver is not as clear, however. In spite of the Egyptians’ *prima facie* understanding of physiology, a less likely, though undeniably possible, alternative is that they simply selected the largest and most obvious organs; organs that fill most of the body cavity.

Their supposed reasons for wanting to preserve the heart seem much clearer. Scarabs placed in the thoracic cavity, the heart scarabs, and the chapter (30B) of the Book of the Dead inscribed upon them, provide ample evidence of the importance of the heart:

“My heart of my mother, my heart of my mother, my heart of my stages of existence, stand not up against me as a witness, tender no evidence against me as a witness. . . Speak not lies against me in the presence of the Great God.” (Iskander, 1980, p. 19)

In the ancient literature (Lichtheim, 2006a,b,c) the heart animated the body, commanded the limbs, and according to the importance placed on it as the seat of intelligence and emotion the heart is often described in the modern literature as *always* being left intact (following Diodorus, 1933, Bk 1, p. 91), returned if accidentally removed, or replaced by an inscribed heart scarab (Dunand and Lichtenberg, 2006; Raven and Taconis, 2005).

In barely more than a quarter of the individuals in this sample, however, was the heart retained in situ. In only one case was the heart possibly sewn back into place, and in one other case was a heart scarab present, presumably to replace the removed heart. With the heart enclosed in its pericardial sac and connected by six major vessels, in addition to the pulmonary veins and arteries severed in lung removal, it is fanciful to consider the possibility of it being accidentally removed by a slip of the scalpel; more so when such accidents would have to occur in nearly seven of every ten cases, followed by the loss of the organ in more than 98% of those cases. That heart absence has coincided with lung retention in four cases further condemns the case for accidental excision. Aufderheide (2003) makes note of the poor preservation of the heart in naturally mummified bodies, but the evisceration and internal natron packing in the anthropogenic Egyptian mummies studied here greatly reduced the desiccation time and the opportunity for microbial action (cf. Aufderheide, 2011). Aufderheide’s reference, too, is to the

loss of macroscopically recognisable myocardial fibre, stating, however, that “it is not uncommon to find the heart’s basic structure defined by these residual tissues even though no myocardium remains” (Aufderheide, 2003, p. 319).

What is apparent from this sample is that retention of the heart in the body following evisceration was a feature of some male elite mummies beginning in, at latest, the Middle Kingdom. Absence of the heart began among eviscerated males in the New Kingdom and, subsequently, among eviscerated females in the Third Intermediate Period. The retention of the heart peaked in frequency (number per period) in the Third Intermediate Period, at the same time as the dramatic increase in evisceration following mummification’s democratisation, and declined steadily until the Roman Period (Fig. 2). Meanwhile, mummies were increasingly absent their hearts from the New Kingdom onward (Fig. 2). Although the data are insufficient to closely examine the sex and status associations of these individuals, it is likely that retention of the heart began among the male elite, as befits its and their importance. As time progressed, the nobles gained increasing access to mummification and retained their hearts. With the democratisation of mummification, however, the commoners being mummified were not receiving the same treatment, possibly to ensure that the elite maintained a more favourable afterlife than their subjects.

In addition to the democratisation of mummification in the New Kingdom (Aufderheide, 2003), supernatural judgement of the deceased for entry to the afterlife included the metaphorical weighing of the heart before Osiris, the occasion about which the heart is being warned in the heart scarab inscription. This invites the possibility that the removal and weighing of the heart had more than a metaphorical importance, perhaps even a symbolic ritual one by this time. Unfortunately, this possibility poses two problems: (1) Why was the heart not returned to the body, as suggested by Anubis’ replacement of the heart in chapter 26 of the Book of the Dead and on the Anubis shrine of Tutankhamun (Assmann, 2005)? and (2) What was done with the heart if it was not returned? The heart may be present in the visceral packages returned to the body after the 20th Dynasty, but few of those can be or have been examined histologically to confirm the suggestion (Sigmund and Minas, 2002). The weighed heart may also have been disposed of among the ritually impure and magically dangerous embalming remains secreted near the tomb (cf. Taylor, 2001), or thrown in the Nile in a fashion similar to that afforded other viscera according to Plutarch and Porphyry. If the heart is a vitally important aspect of the personality and soul(s), as the Egyptian literature supports, then it is strange that it should be absent, even disposed of, regardless of its role in a physical ritual. Such an absence seems diametrically opposed to the spirit of the Weighing of the Heart myth and to the preservative function of mummification generally.

The return of viscera to the body cavity, preserved in linen bundles, may not have been the fate of the excised heart, but it was certainly the case for other organs in some mummies. This sample attests to the internal and external placement of organ packages, and similar shaped linen bundles, from the New Kingdom onward. The placement of organs in packages in the body cavity, rather than in canopic jars, is attributed to the 20th Dynasty, beginning with Ramesses V (Taylor, 2001). Significant levels of tomb robbing in the Valley of the Kings is attested to in legal papyri of the time (e.g. Abbot, Mayer, and Amherst Papyri), and may have prompted internal replacement as an insurance policy against the organs’ loss to theft. The dismantling of the royal tombs at the end of the 20th Dynasty was also likely a strong factor influencing the adoption of this practice, as tombs were stripped by the priesthood of valuable mortuary artefacts and the owners were cached in groups in the Theban necropolis (Taylor, 2001).

Both prior to and following the introduction of the viscera to the body cavity, the cavity was packed with a wide variety of other substances. Owing to a dearth of available information on CT numbers for specific mummification materials, and to their minimal reporting in the literature, a detailed analysis of the presence of specific packing materials was not possible here beyond the basic observations made above.

Anal and perineal tampons were present in members of both sexes and statuses beginning in the Third Intermediate Period in this sample. That only one individual exhibited an anal/perineal tampon without evisceration encourages, with caution, interpretation of the tampon as a sign that evisceration had occurred, in individuals too damaged to assess the body cavity directly. The presence of the anal tampon, however, is not a unique sign that an individual has been eviscerated per anum, and in five

cases among the mummies of the Rijksmuseum of Leiden alone there were anal tampons present in individuals eviscerated transabdominally (Raven and Taconis, 2005).

Artefacts, within the body and the wrappings of the mummy, played an important part in preparation of some individuals for the afterlife in the New Kingdom (cf. Budge, 1893), and amulets are reported to increase in number with the status of the deceased (Salter-Pedersen, 2004). Mummification artefacts, such as the scarab and Sons of Horus statuettes, do not appear in this sample until the Third Intermediate Period, but were present in at least the New Kingdom as attested by the large number (143) included in Tutankhamun's mummy (Salter-Pedersen, 2004). When present in this sample, the mummification artefacts were present only in association with elite mummies. Taken in the context of the democratisation of mummification in these periods (NK and 3IP), and Salter-Pedersen's (2004) observation that a greater number of artefacts were used in better quality mummies, additional elements such as amulets and statuettes (also more and better ushabtis and funerary texts) ensured that the elite were provided with a better quality of embalming and, consequently, a better quality of afterlife. Despite the fact that elite and commoners alike had their organs replaced internally by the Third Intermediate, only the elite received Sons of Horus or other (Ptah-Sokar-Osiris statuette? – cf. Shaw, 2000) statuettes in those packages, in this sample. No clear trend is present in the few cases of incision plate use, besides its apparent beginning as an elite male feature in the New Kingdom, followed by its diffusion to females and the middle class.

Radiological markers

The difficulty in accurately assessing the tissues of the body cavity arises from (1) the greatly reduced size of desiccated tissues, obscuring their shape and position; (2) the greatly reduced density contrast between tissues in their desiccated state, obscuring their presence and differentiation; and (3) the incision and excision of tissues in the embalmer's process of evisceration, further obscuring the shape of the tissues and destroying anatomical relationships. The radiographic examination of the body cavity of mummified human remains has been improved by comparison studies of radiographs and autopsy results (Aufderheide, 2003; Lichtenberg, 1994), but many structures are difficult to visualise at all in plain film radiographs (Aufderheide et al., 2004).

Because of the relatively low contrast resolution of plain film radiographs, relative to CT scans, and because of the superimposition of structures in plain films, CT is more readily able to provide a source of accurate information about body cavity tissues. The three-dimensional information available in CT scans, particularly at the high spatial resolutions available from the current generation of scanners, provides important information about the continuity or discontinuity of structures for their identification. Ongoing research into the use of dual or multiple energy CT (Friedman et al., 2008), wherein different materials attenuate X-rays differently at varying energy levels, is expected to improve differentiation of tissues and mummification materials. The application of additional imaging modalities (e.g. MRI, terahertz EM imaging, and XRF), which are increasingly easy to merge into composite datasets, also holds the potential to increase our ability to discern specific materials and tissues.

The route of evisceration is often easily discernable. If the abdominal skin is intact, the embalming incision on the left abdominal wall is easily appreciable on CT scans and its position and direction may be effectively discerned in three-dimensional reconstructions (Figs. 3A, 4A and 6A). The presence of an incision plate (Fig. 4C), however, may be the only indication of transabdominal evisceration in plain films. The perineal forms of evisceration, and particularly their differentiation, may be substantially more difficult. The accumulation of large amounts of resin at the perineum (Aufderheide, 2003) and the compaction of loose folded skin in this area complicates its assessment (Fig. 8A). The presence of anal, vaginal, or perineal tampons, particularly if their appearance is accentuated by resin-impregnation (Figs. 7C and 10), may aid in identifying discrete structures in this region.

Among the structures present in the body cavity, the heart and lungs are the most readily identifiable by their position. The heart, when it is retained in the chest appears as a dense mass suspended in the pericardium (Fig. 3B), while the lungs remain as thin (<20 mm), flat structures in the dependent portion of the thoracic cavity and may appear as patchy opacity in chest films (Aufderheide et al., 2004; Rideout, 1977; Smith and Wood-Jones, 1910). The inferior border of the lung may be quite defined, retaining its original shape. The pericardium itself appears as a linear opacity; "a tent tethered between



Fig. 10. Plain film radiograph of RM-2717 (a Theban female at the Redpath Museum), showing a dense heterogeneous mass at the pelvic outlet indicative of anal, vaginal, and/or perineal packing.

the sternum and thoracic spine” (Scott et al., 1977, p. 464) and diaphragm (Fig. 8B). The diaphragm also appears as a linear opacity on CT scans (Fig. 6B). The liver appears as a dense mass, reduced in size but retaining its shape, connected by the round ligament to the posterior of the abdomen (Scott et al., 1977). It may also be found adherent to the inferior border of the pericardium (Rideout, 1977). The intestines, stomach, and urinary bladder are reduced to fine, papery, easily disrupted structures (Scott et al., 1977), again appearing as linear opacities, but the intestines may be supported by faecal matter and retain their natural shape as bowel loops (Fig. 9B) and their position. The kidneys are particularly difficult to differentiate, as they are reduced to flattened opacities that may be indistinguishable from other similarly flattened retroperitoneal structures (Aufderheide et al., 2004; Smith and Wood-Jones, 1910).

In the case of wrapped organs, returned to the body cavity, the packages are virtually indistinguishable from one another (Raven and Taconis, 2005). The loss of shape, position, and contrast in the wrapped organs is further aggravated by the frequent presence of large amounts of resin, sharing the dependent portion of the body cavity, which soaks the linen packages (Figs. 3B, 4B and 6B). Organ packages can typically be differentiated from empty linen rolls by their heterogeneous density on CT scans (Figs. 3B and 4B) (produced by radiodensity difference between linen, resin, desiccated organ, and adherent natron), and by the simple lack of volume at the centre of other empty rolls of linen present in the body cavity (Fig. 6B).

Mummification artefacts included in and on the body are often easily recognisable as such, particularly when fashioned from dense materials like stone, faience, ceramic, and metal (Fig. 4C). In the case of high resolution CT scans, it may even be possible to identify and read inscriptions on artefacts such as heart scarabs (Jansen et al., 2002). Anal, vaginal, and perineal tampons are identified by their placement at these orifices, but may be difficult to differentiate from one another in the perineal orifice. Untreated linen tampons may be appreciable, more so when made more radiodense by resin-impregnation, and the latter will be apparent in plain films (Fig. 10).

Resin in the body cavity is also easily recognisable as a high-density, homogeneous material, approaching the radiodensity of bone (Figs. 3B, 6B and C). The relative homogeneity of resin distinguishes it from packing with soil or other dense materials. When introduced to the body cavity in a liquid state, it settles to the lowest point (Figs. 3B, 6B and C), although its temperature and fluidity may allow it to penetrate, even crack, bones (Derry, 1939). Resin is sometimes referred to as demonstrating an air–fluid or fluid–fluid level (Figs. 3B, 6B and C) (Pickering et al., 1990), but is more accurately designated a straight level (Strouhal et al., 1986) or solidified fluid level. It has also been noted that resin introduced to the body cavity may overflow into the cranial cavity and feather or pool there, depending on its temperature (Aufderheide, 2003).

Conclusions

This study demonstrates the difficulty in relying on the classical stereotypes of authors such as Herodotus and Diodorus Siculus. In spite of the lack of detail present in descriptions of mummies throughout much of the literature, there is substantial evidence for (largely unappreciated) variability in the mummification tradition and for that variation's contradiction of the classical descriptions.

The inadequacies in mummification reporting and the reliance on normative classical descriptions highlight the need for more detailed, consistent, and comprehensive descriptions of Egyptian mummified remains (cf. Dageford et al., 2009; Wade et al., 2011; Zweifel et al., 2009). Accurate identification of desiccated organs, or at the least their obvious absence, is an essential component in the assessment of evisceration's variation and evolution in Egyptian mortuary ritual. Computed tomography data, merged at multiple energy levels (e.g. Friedman et al., 2008) with data from other imaging modalities (e.g. Rühli et al., 2007), provides a high-resolution, non-destructive means by which to adequately assess this variability.

This study addresses the hypothesis that, were the descriptions of evisceration by Herodotus and Diodorus accurate and adequately representative, one would expect to see (1) transabdominal evisceration only in the elite, (2) frequent anal enema evisceration among the commoners, and (3) near universal retention of the heart in eviscerated mummies. Rather, the empirical data demonstrate transabdominal evisceration in large numbers in both social classes. Not only are anal enema eviscerations not clearly present, evisceration by any means in the perineal region is restricted to elites in the few cases that are reported. Finally, the position that the heart was always left in place, replaced if accidentally removed, and replaced by a heart scarab if not returned, is far from the truth.

The hypothesis constructed from the stereotyped accounts by Herodotus and Diodorus is falsified by the data (cf. Wade et al., 2011, for a similar conclusion regarding excerebration), and these classical descriptions should only be considered as, at best, a possible snapshot of mummification performed by one particular workshop; a snapshot that does not express the full range of variation in the practice throughout the entirety of Egypt over the course of three millennia, nor necessarily even the period in which the account was written.

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