



First-time complete visualization of a preserved meningeal artery in the mummy of Nakht-ta-Netjeret (ca. 950 BC)

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Abstract

The preservation of the meningeal artery in ancient mummified bodies, particularly in anthropogenic Egyptian mummies, is a highly controversial topic in neuroscience and anthropological research. A recent (2015) debate between Wade and Isidro, based on the interpretation of the meningeal grooves and cast in a skull from the necropolis of Kom al-Ahmar Sharuna (Egypt), highlighted both the necessity of having clear radiological descriptions of this anatomical structure and of assessing large collections of mummified crania. Here, we present for the first time an instance of extremely well-preserved middle meningeal artery in the mummy of the ancient Egyptian dignitary Nakht-ta-Netjeret (ca. 950 BC), still inside the meninx, using paleoradiological techniques. We finally link this find with experimental data from the neurological literature on the methodology of excerebration implemented by ancient Egyptian embalmers.

Keywords Meningeal artery · Neuroanatomy · Neuro-imaging · Ancient Egypt · Mummies · Anthropology

In 2015, Isidro and colleagues presented an interesting case of a cast of the middle meningeal artery with its branches, anterior and posterior, adhering to the inner vault of the skull of individual “W19” from section B of the UE.4013 sector of the vast Necropolis of Kom al-Ahmar Sharuna, Egypt. This represents the effect of massive pouring of resins into the cranial cavity during the mummification process, as typical of the Late Period/Ptolemaic Period (550–150 BC) to which the mummy belongs [1]. The cast was considered an exceptional find that matched the more ordinary detection of the impressions left upon the inner surface of the parietal bone and the squamous part of the temporal bone, which had long before been described by anatomists [2].

The uniqueness and genesis of this find was disputed by A. Wade [3] who highlighted how instances of preservation of cerebral structures in anthropogenic mummies, inclusive of meningeal layers, are somewhat common in anthropological research on ancient human remains. Isidro countered that,

while preservation of brain structures in mummies is not in dispute, reports on the preservation of meningeal structures and their vessels are indeed scarce [4]. Both interpretative stances can be agreed upon since only a study on a large sample size, combining CT scan analysis and macroscopic observation on autopsied or fragmented mummified bodies, might really elucidate the matter once and for all.

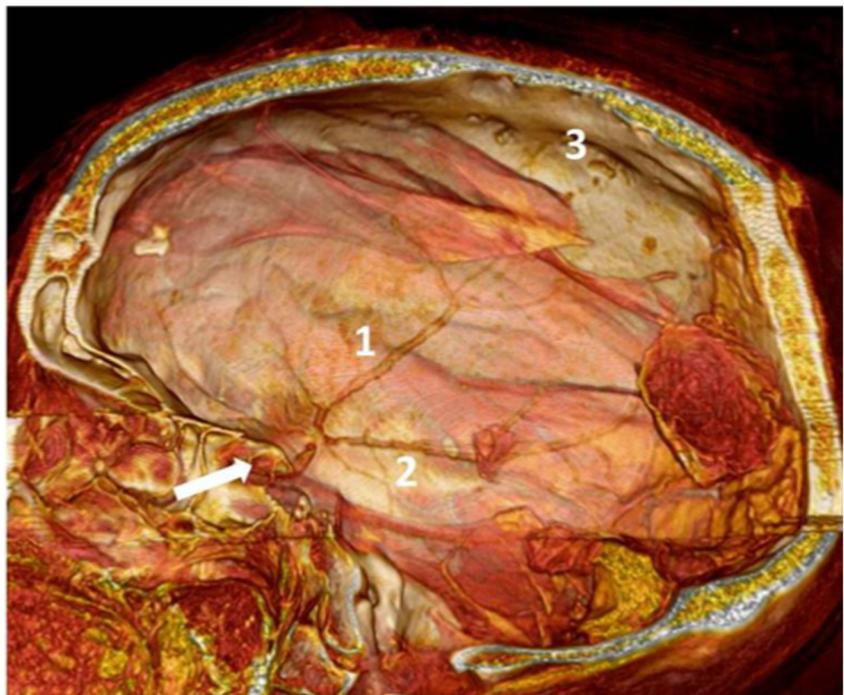
One aspect of Isidro’s argumentation particularly caught our attention, namely the fact that, when meningeal anatomy preservation is discussed, limited photographic or radiological evidence has been provided in the anthropological and paleopathological literature so far. With particular reference to the case of the preservation of meningeal vessels, we aim to contribute to the ongoing discussion by complementing previous debates with a better visualization of these anatomical structures in ancient mummified human remains.

Here, we present the case of an extremely well-preserved right middle meningeal artery within the skull of Nakht-ta-Netjeret (henceforth *Nakht*), an ancient Egyptian dignitary from Thebes deceased at an age of about 40–50 years, whose mummy is exhibited in the *Musée d’Ethnographie de Neuchâtel* (Switzerland) [inventory number: Eg. 185.c.] [5]. The artery enters the cranial cavity through the *foramen spinosum* of the sphenoid bone and runs across the inner surface of the temporal and parietal bones, branching into smaller vessels.

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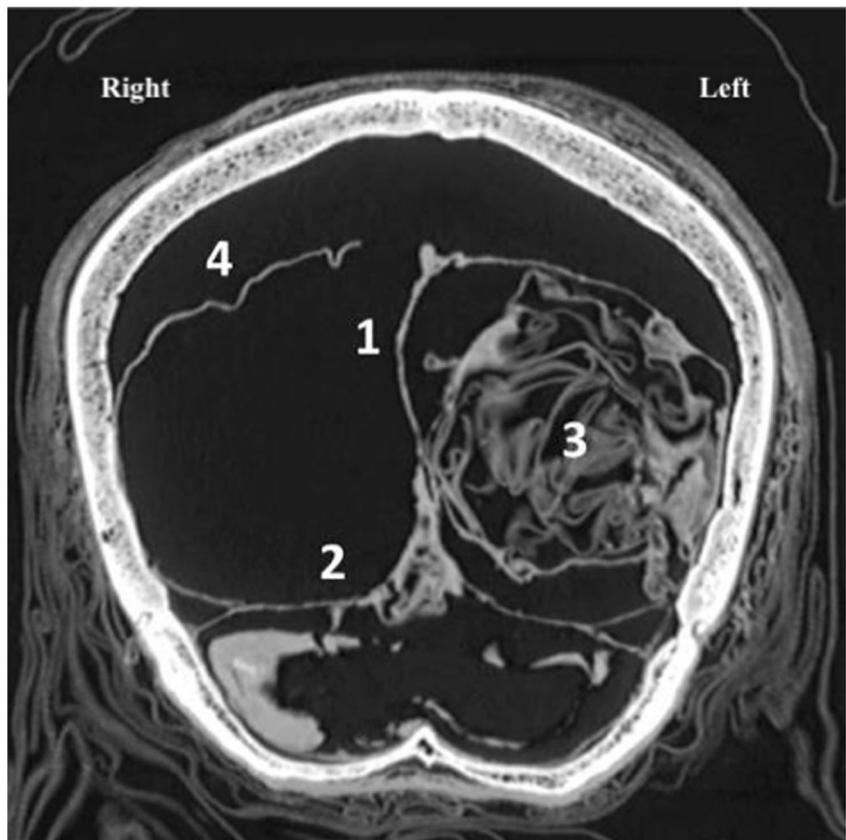
Fig. 1 Multiplanar reconstruction and 3D volume rendering of CT scans of the mummified head of Nakht-ta-Netjeret (ca. 950 BC) [Musée d'Ethnographie de Neuchâtel; inventory number: Eg. 185.c.]. Arrow: Perforation in the skull base for excerebration purposes, 1: *middle meningeal artery (MMA), anterior branch*; 2: *posterior branch*; 3: *arterial grooves*



The form of Nakht's coffin is definitely in the Theban style, particularly of the so-called yellow style from the later 21st to the beginning of the 22nd Dynasty (ca. 960–900 BC), which

reached its peak of use during the period going from the reign of Pharaoh Siamun to that of Osorkon I. From a purely Egyptological perspective, in the case of the Neuchâtel

Fig. 2 CT coronal section of Nakht's head. 1: *falx cerebri*; 2: *tentorium cerebelli*; 3: *intracranial tamponade*; 4: *detached Dura mater*



mummy, the lid and the container of the wooden coffin seem not to have originally belonged to each other (as the lid is very carefully made and the container of an average quality); hence, an absolutely confident identification based on the coffin alone is not possible. Inside it lies the well-preserved mummy of a man which was unwrapped in 1896 and re-wrapped in modern times only leaving the face uncovered: five amulets were found, including a heart scarab made of black stone bearing the individual's name and his titles: Nakht-ta-Netjeru ("Victorious is the Goddess"). Nakht was a gatekeeper of the temple of Mut (a celestial goddess and mighty divine mother) in the temple complex of Karnak. Considering this position was quite low in the priestly ranks, his mummification is of surprisingly high quality. It is by far certain who the actual owner of the coffin was, as this reports a different—yet similar—profession of a "servant of the first prophet of Amun, King of the Gods" and "deputy" but no name [5].

From a paleopathological perspective, Nakht's lower limbs show clear signs of arteriosclerosis, affecting all three tibial arteries. The heart was removed during the embalming process. CT analysis of Nakht's mummy was performed in 2013 at the Institute of Forensic Medicine of the University Zurich (Zurich, Switzerland) using a Siemens Somatom Definition Flash (Erlangen, Germany) scanning device, with the following imaging parameters: slice thickness 0.6 mm; X-ray tube current 579 mA, KVP 120 kV. Multiplanar reconstruction and 3D volume rendering were obtained using OsiriX-64 bit (version 5.8.5).

The CT scans of Nakht's mummy make the process of excerebration visible. In a surgically precise manner, the base of the skull was pierced with a chisel through the nose in the area of the sphenoid bone and an instrument—the "iron hook" mentioned by Herodotus in his *Histories* (II,86)—was inserted through the small opening (1.3–1.5 cm) deep into the skull (Fig. 1, arrow). The brain was then probably dissolved with this instrument—although it might have already partially decomposed—without disrupting the meninges with their annexed vessels. Hence, the *falx cerebri*, too (Fig. 2.1), and the *tentorium cerebelli* (Fig. 2.2) are clearly visible on CT scans. The brain could finally flow out from the nose; the cranial cavity was rinsed out and partly tamponated. The tamponade can be followed through the right nasal passage, then through the perforation in the cranial base backwards into the space delimited inferiorly by the left *tentorium cerebelli* and medially by the *falx cerebri* (Fig. 2.3). In the right upper part of the cranium, the meninx is slightly detached from the parietal bone (Fig. 2.4). Thus, in the 3D reconstruction, not only can the *middle meningeal artery* (MMA) with its *anterior* (Fig. 1.1) and *posterior* (Fig. 1.2) branches be seen on the *Dura mater*, but also their grooves, the *sulci arteriosi*, are visible on the parietal bone (Fig. 1.3).

However, these findings do not correspond to the results obtained through experimental excerebration, such as those performed by Sudhoff [6]: "When one entered the skull, the tentorium and all opposing fixed membrane parts within the skull were torn [with the hook ...] the slightly macerated brain stirred and then the corpse laid on the abdomen, so the brain ran out almost completely in 15–20 minutes [...]." Additionally, Brier [7] "required for removal of the brain the destruction of the membranes and the liquefaction of the soft tissues." He describes this maceration, as indicated by Sudhoff, as the crucial element "This was a procedure that certainly the ancient embalmers could have followed, and we now believe that it probably was."

In conclusion, even after 500 years of discussion, the questions about the technology of excerebration have not been fully answered. Yet, a better radiological visualization of the meningeal vascularization has been provided at last. Further studies are, undoubtedly, needed to fill out this still existing *lacuna* in anthropological research.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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