Revealing the Secrets of Animal Mummies with Canon Technology

Merijn de Bakker, Mike Richardson, Berend Stoel, Irene Hernández-Girón, and Lara Weiss.

The Rijksmuseum van Oudheden (National Museum of Antiquities, RMO) in Leiden has one of the ten most important collections of the ancient Egyptian culture worldwide, among which are several animal mummies. In order to reveal their secrets, the RMO has teamed up with Canon Medical Systems Europe in Zoetermeer, the Netherlands, computer scientist Berend Stoel and physicist Irene Hernández-Girón (Leiden University Medical Center), and Leiden University biologists Michael Richardson and Merijn de Bakker. The 3D-digitization and interactive visualization of CT allow digital autopsies without any damage to the ancient artefacts!





Mike Richardson (Biologist at Leiden University), Lara Weiss (National Museum of Antiquities, RMO), Ravi Somaroe (European Clinical Specialist CT at Canon Medical Systems Europe) and Berend Stoel (Computer Scientist at the LUMC).

Why animal mummies?

The ancient Egyptians were full of the joys of life and they sought to extend it into eternity. Already during their lifetime they invested heavily into tomb building, and eventually, after death, mummification. Only an intact body could survive in the afterlife. Occasionally Egyptian pets were also mummified to keep their owners company, yet most animals mummified were not domestic animals. They were bred in the temples of the gods. The animals were killed, mummified and then sold to temple visitors, who bought these so-called 'votive mummies' in order to donate them to the gods in return for their favour. This practice flourished on an almost industrial scale from the 6th century Before Common Era to the 2nd century Common Era. The ancient Egyptians thus did not worship animals per se, but the idea was that some divine powers could manifest themselves in animal form. For example, the power of dangerous animals such as crocodiles or snakes could be converted and used as a protective force.

The underworld god Anubis was a jackal god. Perhaps he became a protector of the deceased, because wild dogs were frequently seen on the desert plateaus where tombs of the deceased were located. Other animal forms are less evident. The god Thoth was associated with the art of writing and wisdom. He could appear as ibis-headed human, as ibis, or as baboon. The fertility goddess Bastet could appear cat-headed or as a cat, sometimes with several kittens. At Saqqara, about 30 km south of modern Cairo the so-called necropolis of the sacred animals was situated. This was an area of underground catacombs, several temples and shrines. The mummified ibises, baboons, falcons, and dogs were buried in separate catacombs, whereas at Saqqara cat mummies mostly appear in reused earlier tombs.

Digital autopsy

The RMO has a large collection of mummies, because the museum did not unwrap them. The very first director of the museum had already realized in the 19th century that the unwrapping of the more than 2000-year old mummies meant destroying them forever. This was a very wise decision although it would take some patience and time to learn more about the Leiden mummies. X-rays had been discovered in 1895 by Wilhelm Röntgen and started to be used as a non-invasive method to obtain medical images of the interior of the human body one year later. It took until the 1960s to apply radiographs to investigate the first Leiden mummies. X-ray imaging allowed non-destructive investigation of the hidden interior of the ancient remains. In 1972 the first commercial computed tomography (CT) system was released for clinical use, and almost a decade later, the first Leiden animal mummies were scanned (1981). The 1990s saw CT scanning of the whole mummy collection in collaboration with the Amsterdam Medical Center (AMC)[1].

In 2016 two Leiden mummies – a man and a crocodile – were CT scanned again in cooperation with AMC. It was now possible to digitally unwrap the mummies layer by layer in a 3D-model. The latest developments in Computed Tomography image reconstruction, based on deep learning methods, have the potential to boost overall image quality by reducing noise, enhancing edge sharpness while minimizing artifacts[2,3] compared to previous iterative reconstruction methods. Therefore, in this study, the deep learning reconstruction technology developed by Canon Medical Systems, called Advanced intelligent Clear-IQ Engine (AiCE), was used in combination with one of their latest CT systems (Aquilion ONE / PRISM Edition) to unveil the secrets of the Leiden animal mummy collection.

© 2020 CANON MEDICAL SYSTEMS // CTEU200150



Lara Weiss (National Museum of Antiquities, RMO) with the Ibis mummy.

Inside and out: what's under the wrappings

On February 19th, 2020, seven animal mummies were scanned at Canon Medical Systems Europe B.V. in Zoetermeer as a first test case of the ideal settings of the Aquilion ONE / PRISM Edition scanner, applying the latest reconstruction method available, AiCE. Some of the mummies had been previously scanned in other CT systems and using other medical modalities, such as conventional X-ray imaging, so prior to scanning no big surprises were expected.

In this particular study, in which the mummies are old and fragile, the imaging protocols had an associated dose at a similar level as used in clinical practice with patients.

Despite the initial modest expectations, the high resolution of the new scans, even on the reconstructed axial slices with AiCE, already allowed the identification of structures inside the mummies not seen in the previous studies.

Additionally, the high resolution of the scans combined with Global Illumination software at the Vitrea workstation from Vital, enabled the creation of highly detailed 3D-models of the mummies. Applying thresholding, the visualized tissues could be custom selected, and the full control over the visualization angle and rotation of the mummies in space, allowed us to virtually unwrap layer after layer of fabric from the mummies without any damage.



Ravi Somaroe (European Clinical Specialist CT at Canon Medical Systems Europe) and Berend Stoel (Computer Scientist at the LUMC) scanning the mummies.



Crocodile mummy Leiden inv. no. AMM 16h

This crocodile mummy's wrapping was designed with a lot of attention for detail. Inside is not a juvenile crocodile, but only a skull, without lower jaw, of an adult crocodile. It seems to have been somehow attached to a stick extending through the whole mummy.



Head of a dog mummy - Leiden inv. no. AMM 16m

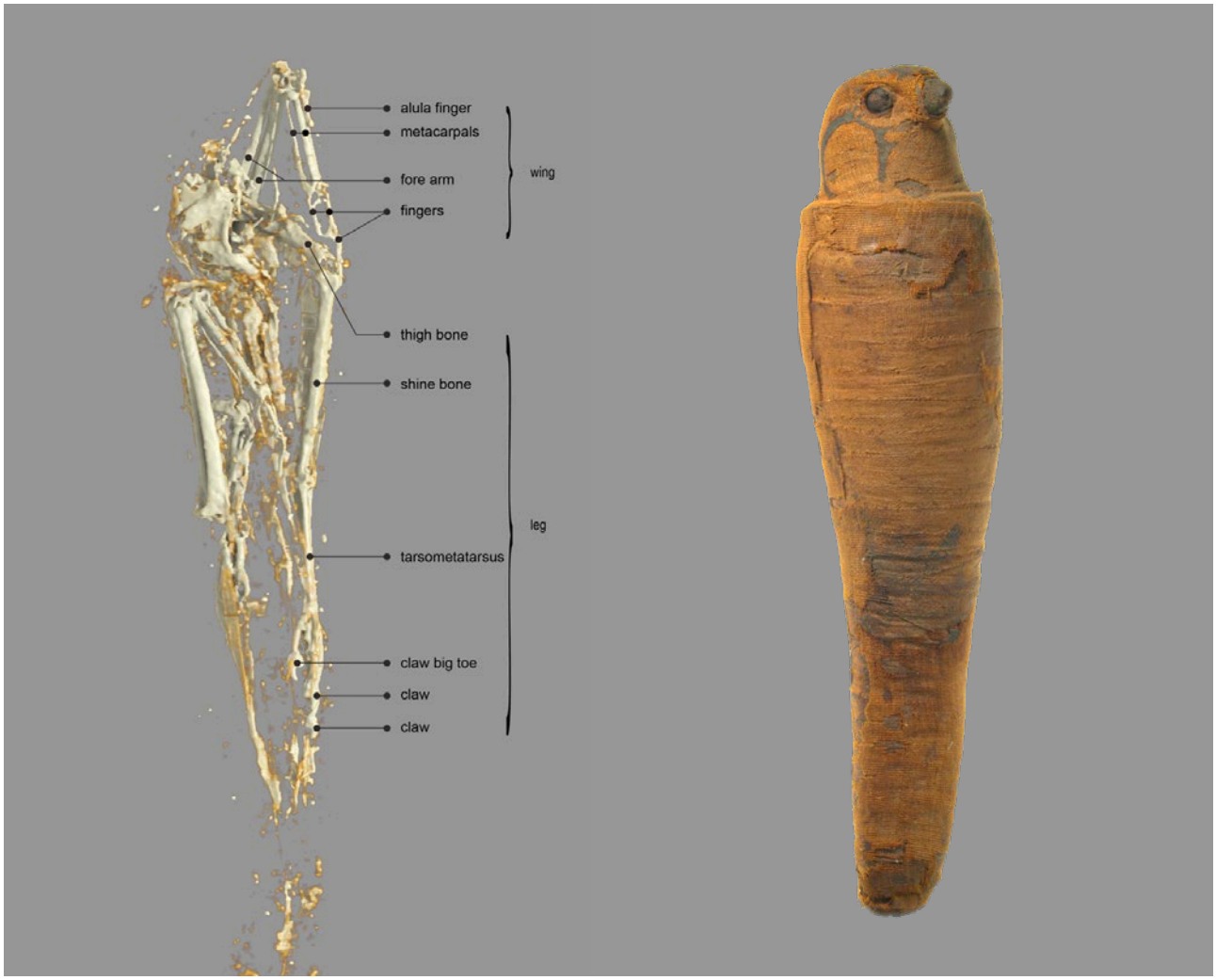
The mummified dog head is a nice example of how a CT scan help understanding what kind of objects we are dealing with. It was purchased by the museum as an animal of unknown type in 1828, and long thought to be an ibis mummy, until a scan on 15 May 2000 revealed it was actually the head of a dog. It is odd that the head was mummified separately, which is highly unusual. The question is therefore whether it was a gift for the jackal god Anubis, the protector of the deceased and god of mummification, or whether the parcel was meant to look like an ibis mummy, in which case it would be an ancient 'fake' mummy.



Fish mummy - Leiden inv. no. CI 259

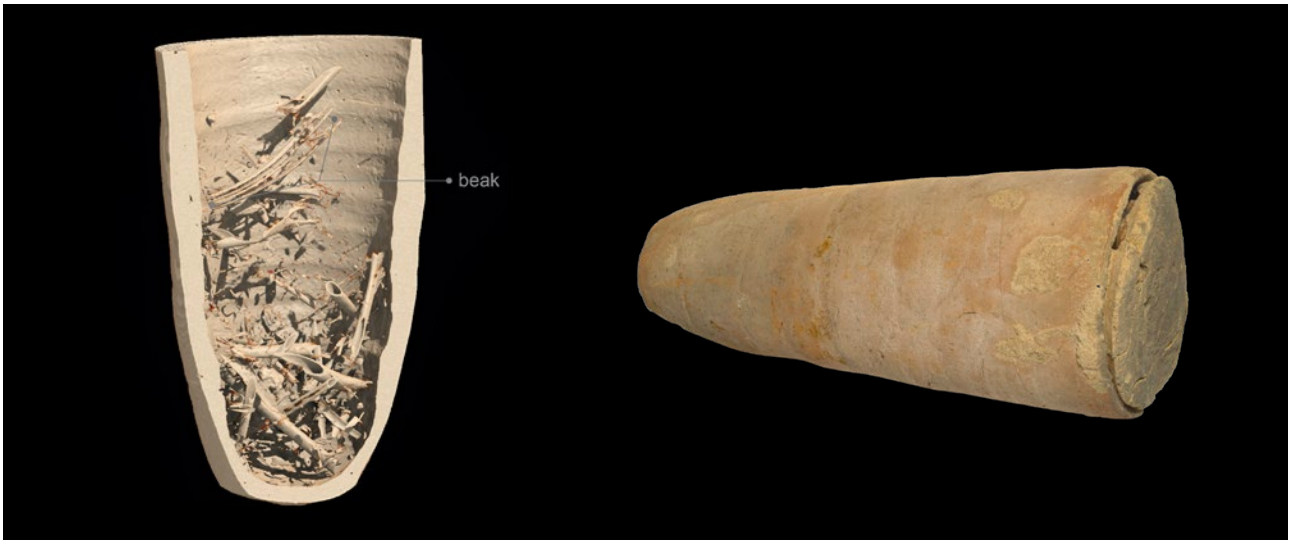
This mummy has its own fish-shaped coffin. Inside is a small fish, identified as Nile perch in earlier publications, of which the head points to the tail end of the coffin. Nile perch were associated with rejuvenation since they lived in the primeval waters of the river Nile. Yet the determination of the fish species is difficult. Nile perch adults can weigh over 100 kg, so while it may be a juvenile Nile perch it could as well be almost any other fish. The coffin seems to have the shape of a Nile tilapia, but this is not indicative. Christian Tudorache and Merijn Bakker did not see any vertebra only a few fin rays of which it is unclear if they are pelvic, pectoral or anal, and what seems to us the head is pointing to the tail end of the coffin. None of its characteristics points to a specific species of fish endemic to the Nile. For a better identification of the fish we would need information of the head and the kind of teeth the fish had, which are invisible in the current scan. We are therefore greatly looking forward to further technical developments by Canon Medical which will improve image quality even further, and will potentially reveal even more information about our mummy collection, and maybe other museum collection items.

© 2020 CANON MEDICAL SYSTEMS // CTEU200150



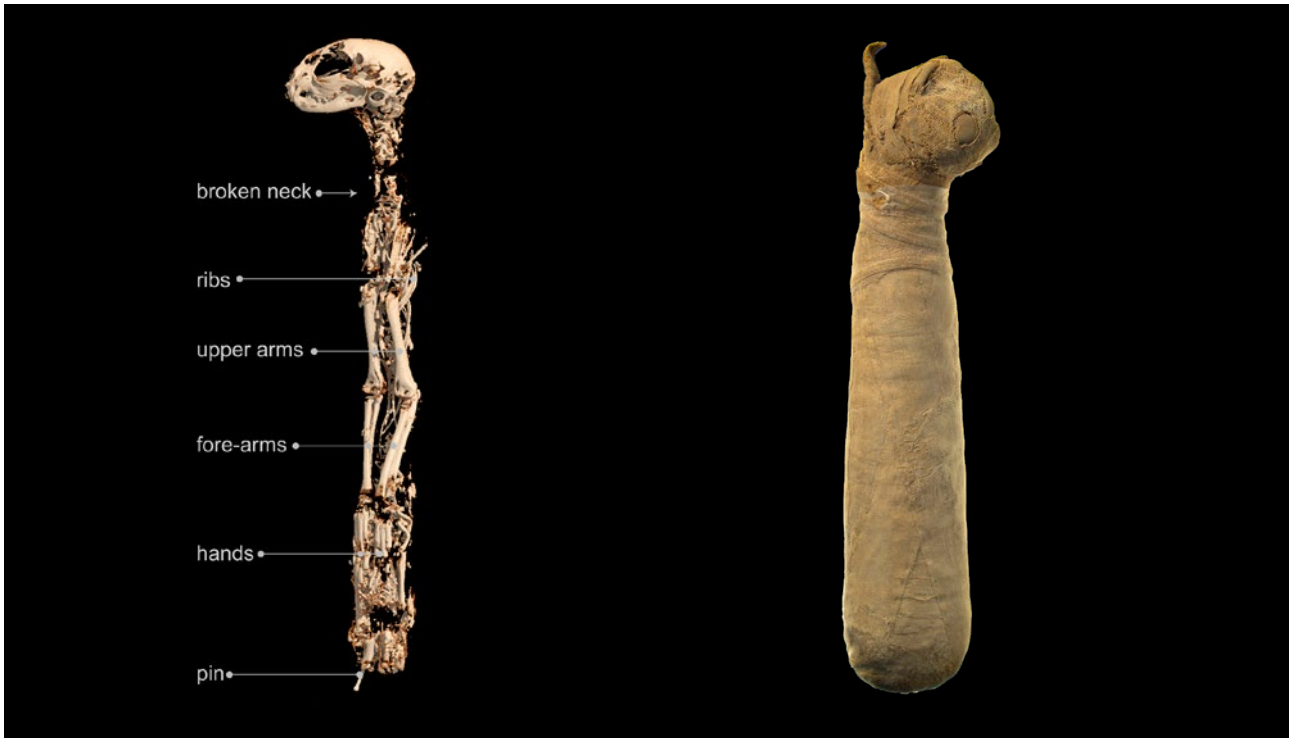
Falcon mummy - Leiden inv. no. F 1982/12.10

In an earlier publication, scholars were uncertain if the mummy was a falcon or a sparrow-hawk. The former has now kindly been confirmed by Hanneke Meijer. The falcon mummy consists mainly of its limbs but is missing most other bones, including its head. This does not mean it was a fake since in Egyptian religion, one part could symbolize the whole (pars pro toto).



Ibis mummy in ibis pot - Leiden inv. no. H.III EEE 3

Other typical examples of ibis mummies are little vases known as 'ibis pots'. The bird mummy inside this ibis pot is incomplete, but the curved beak, the bones of both upper and lower beak, in the top of the pot identify it as an ibis. At the bottom of the pot is a collection of mainly broken hollow long bones from the wings and legs. This specimen was different to the others, from the scanning point of view, as the vase has a high X-ray attenuation, similar to dense bone. Despite of this, the images show a high level of detail and sharpness, depicting all the small bone chips remaining of the ibis.



Cat mummy - Leiden inv. no. AMM 16 cm

Cat mummies were gifts for the tutelary goddess Bastet. This relatively young and otherwise healthy animal was killed by breaking its neck. It is mummified in an unnatural upright position with its arms alongside its body. The body is also squashed flat and the ribs are out of position, you can also see some of them between the fore-arms. As a part of modern restoration, the animal was fixed with modern pins.



Ibis mummy - Leiden inv. no. F 1956/10.4

This complete juvenile ibis was mummified with its head bend down between its legs (the long hollow bones typical for birds). The curved upper and lower beak are clearly visible at the bottom.

Acknowledgements

We should thank Hanneke Meijer (University of Bergen, Norway) for her help in analysing the bird mummies and Christian Tudorache (Leiden University, Netherlands) for analysing the fish mummy. //

References

[1] *Raven, MJ and Taconis, WK. Egyptian mummies: radiological atlas of the collections in the National Museum of Antiquities at Leiden, Turnhout 2005.*

[2] *Willemink MJ, Noël PB. The evolution of image reconstruction for CT – from filtered back projection to artificial intelligence. European Radiology (2019);29(5):2185-2195*

[3] *Singh R et al. Image quality and lesion detection on deep learning reconstruction and iterative reconstruction of submillisievert chest and abdominal CT. AJR (2020);214(3):560-573.*

© 2020 CANON MEDICAL SYSTEMS // CTEU200150