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Why did the Egyptians Use Natron for Arteficial Embalming? - An Experimental Study on Organ Mummification

Andreas G. Nerlich, Judith Falter, Albert Zink

Division of Paleopathology, Department of Pathology, Academic Hospital Munich-Bogenhausen, Englschalkinger Str. 77, D-81925 Munich, Germany

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Abstract

The high standard of artificial mummification in ancient Egypt seems to result from a long period of empiric assessment. However, it still remains unclear why the ancient Egyptians used specific dehydration substances, such as natron, and not other comparable ones, such as sea salt (widely used for conserving foodstuffs). In order to contrast the effect of natron and salt in artificial mummification, we compared two pig hearts of similar size. One was embedded in natron, the other in sea salt up to 69 days at 37°C using Egyptian mummification procedures. The total weight of the two samples differed significantly during the period of observation, but was most obvious during the first 5 weeks. The heart in natron dehydrated more rapidly than the heart in salt. Histological tissue preservation was better in the natron sample. We suggest that empiric observations led the ancient Egyptians to realize the functional advantages of natron over sea salt, leading to optimal conservation of cadavers.

Introduction

The ancient Egyptian´s expertise to conserve cadavers is still a major miracle. Taking the long period of ancient Egyptian civilization into account - the high standard of arteficial mummification seems to have resulted from a long period of empiric assessment. However, it still remains unclear why the ancient Egyptians specifically used certain substances, such as natron, and not other conservatory substances, such as salt from the seaside (which e.g. is widely used in the Northern hemisphere for conservation of nutrients, e.g. fish) or other conservation substances, such as metal salts. Besides arguments of availability of all those substances, in particular questions as to recover and transport of particular substances, we here systematically analyzed the "biologic potential" of sea salt in comparison to natron which was preferred by the ancient Egyptians. Thereby, we provide a plausible explanation for the preferential use of natron during embalming instead of sea salt, analyzed on an experimental model of freshly obtained pig hearts. Furthermore, this experimental investigation sheds some interesting light on the velocity of tissue drying under the influence of particular embalming substances and the consequences on macroscopical and histological tissue conservation. Finally, we compared the experimental data with the analysis of ancient Egyptian heart muscle tissue that had been obtained during a recent excavation and that served as a "biologic control" of the experimental system.

Material and Methods

In order to identify the effects of natron versus salt during arteficial organ mummification, we compared the application of both conservatory techniques on two complete hearts that had been obtained from two pigs of comparable size. The embalming protocol as strictly followed the information given by Herodotus as possible with respect to the dehydration substance and the time courses.

Both hearts had been freshly obtained from the slaughter house. Both ventricles had been opened by incision to remove blood clots. Then comparable amounts of either natron or sea salt were filled into the ventricles as well as applied to the surface. Subsequently, both organs were wrapped in linen bindings of identical length.

Both organs were then stored for up to 69 days in a 37°C oven. The weight of both samples was determined in approx. 7 day intervals and at those time points small tissue samples of comparable size were removed for histopathological analysis. Therefore, these tissue samples were immerged into a rehydration solution that had successfully been applied to mummy tissue samples before (Nerlich et al., 1995). This solution contained 2-4% buffered formaldehyde, pH 7.4, with decreasing solutions of a detergent (Brij). Following 24 - 48 h fixation with slight stirring and frequent renewal of the solution the samples were embedded into paraffin wax according to routine protocols.

The following parameters were evaluated:

– macroscopic appearance of the organ´s surfaces

– organ weight curve
– histological appearance of preservation of cell nuclei, cell margins, striation of muscle cells, connective tissue preservation and blood vessel conservation (Nerlich et al., 1995);

The experimental observations were compared to an ancient Egyptian heart sample from an adult human male individual dating back to approx. 1200 - 1400 BC. This case has been described previously to have suffered from mild coronary arteriosclerosis (Nerlich et al., 1997). A small sample of this heart muscle was available for histological analysis in parallel to the above indicated procedure. Here again the histological features indicated before were regarded.

Additionally, a fresh human heart tissue sample was obtained from a recent human autopsy in order to secure the comparability between the pig and human heart tissue. Accordingly, there was no histologically evident difference between the human and the pig heart tissue.

Results

Both organs were unwrapped after 35 days, then refilled with natron or sea salt and again rewrapped after 69 days. The macroscopic appearance of both organs differed at both time points. Thus, the natron treated heart seems to be more shrunken than the sea salt treated one at the 35 days time point (Fig. 1) which was less evident at 69 days.

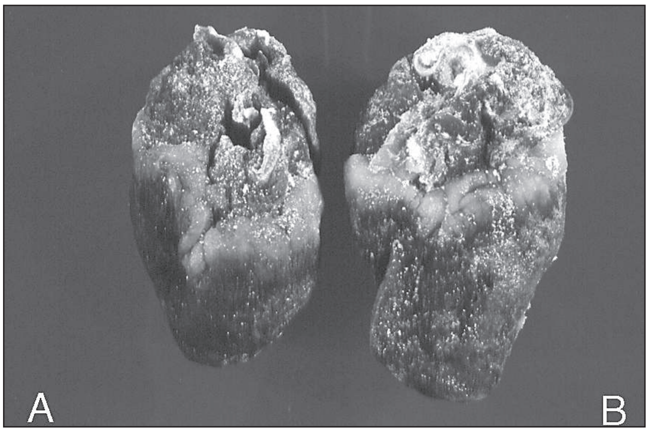

Fig. 1 - Macroscopic appearance of the two experimentally treated hearts, 35 days after starting the mummification process; (A) The natron treated organ is dark brown and slightly more shrunken; (B) The sea salt treated organ shows slight greenish surface areas suggesting superficial postmortal decay.

Additionally, the surface of the sea salt treated organ appeared lighter and showed a slight green colour touch. With respect to the total weight of the two experimental settings, the organ weights differed significantly during the complete period of observation, although the difference was most obvious during the first 5 weeks. Thus, the natron embedded heart was much more rapidly dehydrated than the salt embedded. Likewise, the natron treatment lead to a loss of approx. 50% of weight within 10 days, while the sea salt treatment resulted in only 20% loss of weight. At approx. 18 days the natron treated heart weighed only 40% of the fresh weight which was not significantly enhanced until 69 days. In contrast, the sea salt treatment showed a gradual decrease (to 70% at day 18 and 50% at day 52 and 69). Interestingly, the weight reduction of the sea salt treated did not reach the natron treated organs level (Fig. 2).

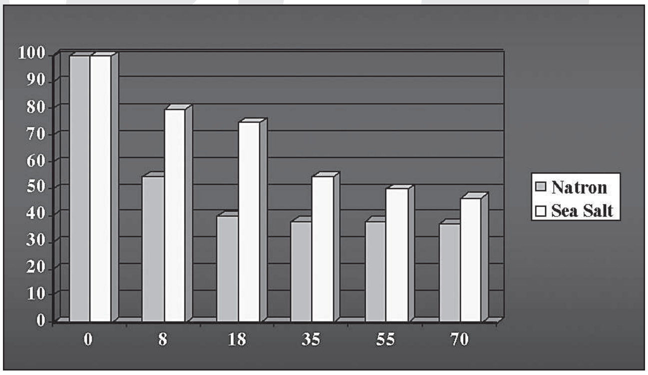

Fig. 2 - Graph of the heart weights for the two experimental settings over the time.

Concomitantly, the histological tissue preservation was significantly better in the natron embedded sample. In general, the two experimental samples showed significantly better conserved tissue structures than the ancient Egyptian one with cell nuclei being still preserved (Fig. 3). In

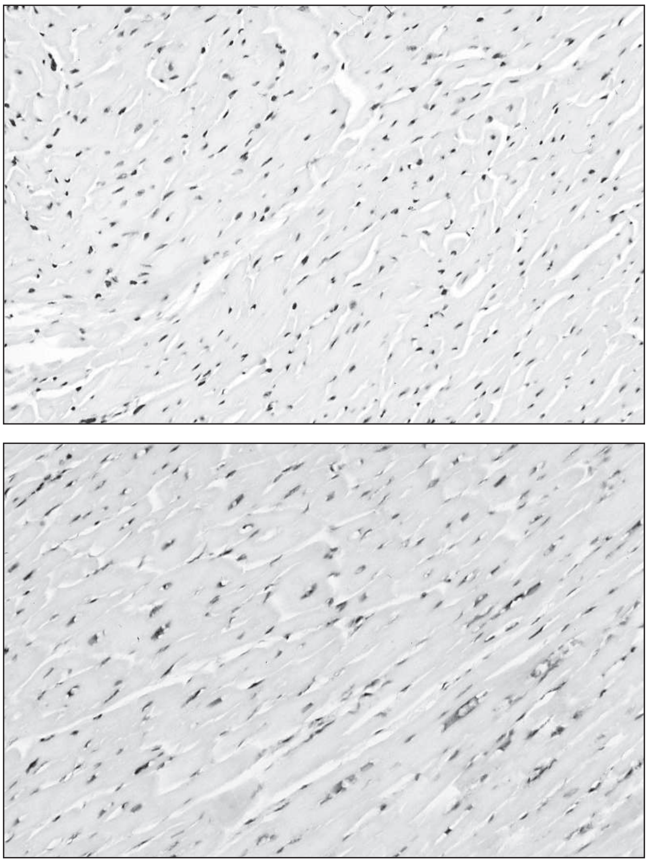

Fig. 3 - Histological features of the experimentally treated organs showing good conservation in both settings with slightly more preserved histo-structures in the natron treated (A) than sea salt treated organ (B) (H&E, original magnification x 450).

detail, all samples showed still preserved cell nuclei and muscle cell striation, however a loss of cell margins in the sea salt treated organ by day 24 which even exceeded in further time points. Both the connective tissue and blood vessel conservation were very well in all samples with adequate features in both conditions.
Finally, we compared the histological features between the two experimental settings and the ancient Egyptian mummy heart (Nerlich et al., 1997) (Fig. 4). There were significant differences between the freshly prepared tissue samples and the ancient tissue material with most prominently the complete loss of cell nuclei in the ancient heart tissue while the cell nuclei were still preserved in the experimentally mummified heart tissue samples. However, even in the ancient tissue material focally the typical striation pattern of the heart muscle cells was still identifiable as was the connective tissue and the blood vessels. Additionally, the mummy heart revealed small typical intracellular droplets of lipofuscin deposits which are usually seen in heart muscle cells as the remnants of chronic intracellular metabolic debris.

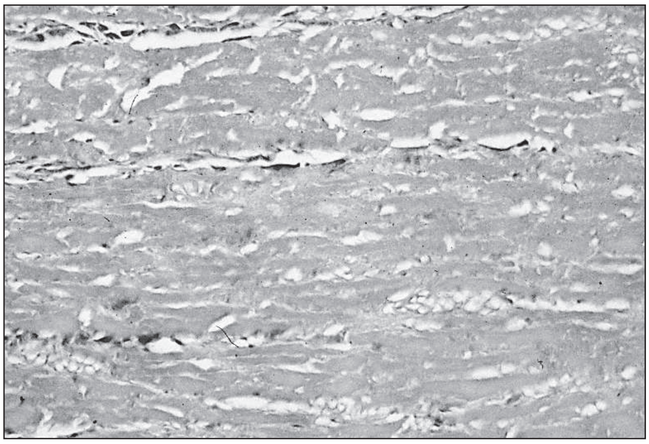

Fig. 4 - Histological appearance of the ancient Egyptian mummy heart. Although the cell nuclei have completely disappeared - in contrast to both experimental settings - the ancient heart tissue and the experimentally mummified organs are similar in the preservation of muscle cell striation and well preserved connective tissue and blood vessel structures (H&E, original magnification x450).

Discussion

This is one of the few studies that analyze major aspects and conditions of the embalming procedure of ancient Egyptians. Up to now, only the studies by Lucas (1932) and Garner (1979) have studied the influence of natron (in different compositions) and sea salt on the mummification of biomaterial. These studies clearly indicate the superiority of natron over sea salt with respect to tissue preservation. However, no histological investigation was performed and all experiments were performed on small animals (laboratory mice) for handling purposes which may only roughly be comparable to the large corpses/organs of humans. Despite these differences, both previous studies confirm the excellent dehydration properties of natron which reaches approx. 65% (Garner, 1979) and which is very well comparable to the findings in our present study. As yet it is generally accepted that the main substance for this procedure was natron salt, a substance that originally occurs in the North Egyptian desert. Likewise, this substance that mainly contains sodium carbonate is found in the Wadi Natrun, a valley running parallel to the Western Nile arm of the Nile delta region. Natron - and especially the sodium carbonate - is strongly hygroscopic and thereby significantly enhanced the dehydration of all biologic material. The rapid dehydration consequently inhibits all destructive processes that destroy biological material, such as the dead human corps, which are usually executed by bacteria that digest the human body proteins.
Although all physical archaeological evidence indicates the application of natron (Lucas, 1932; Winlock, 1941) and the availability of this particular substance is evident from the above indicated source we have as yet no idea why the ancient Egyptians did not use other potentially available dehydration substances. Likewise, sea salt - which is widely used as conservative of meat and fish in Northern European countries - would have also been available. Other potential conservation substances, such as metal ion salts, in contrast are less well accessible. Additionally, these latter substances mostly are very toxic and therefore less easy to handle.
Besides the good availability, we are provide clear evidence that the use of natron had also major functional advantages in embalming human bodies and that this substance is superior to sea salt. This comes from both the velocity of desiccation which was much more rapid than under application of sea salt, the intensity of desiccation which was more efficient with natron than sea salt and the histological degree of tissue conservation that was better when natron was used than sea salt. In summary, we can provide several independent points of evidence that natron desiccates human tissue more efficient than sea salt. This may come from the strong hygroscopic properties of natron that provides objectively better conservation than with the sea salt.
In conclusion, we suggest that empiric observations led the ancient Egyptians to realize the functional advantages of natron than sea salt embedding of organs/corpuses leading to optimal conservation of cadavers.

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