

Mummification to plastination

Revisited

Muhammad Saeed, MBBS, M.Phil, Amin A. Rufai, MBBS, PhD, Saleh E. Elsayed, FRCS, PhD.

ABSTRACT

A brief summary of the history of anatomy is presented with particular focus on important scientists who contributed significantly to the development of anatomical education and recognition of anatomy as a discipline of science. An attempt has been made to review the history of preservation of human cadavers from earliest mummification methodology used by ancient Egyptians to the most modern technique of embalming and plastination of human cadavers, developed by Von Hagens during the period from 1979 to 1987. The need for use of modern teaching aids for instruction of topographic anatomy is also highlighted.

Keywords: Mummification, embalming, plastination, anatomy.

Saudi Med J 2001; Vol. 22 (11): 956-959

Anatomy, the backbone of medicine and fundamental to medical practice,¹ was first recognized as a discipline of science in Alexandria.² The acquisition and retention of knowledge is accomplished by the process of cognition, conation and psychomotor activity. The psychomotor activity trains the individual in spatial appreciation and orientation, which is essential for acquisition of skill and experience. The psychomotor component of learning anatomy is achieved by dissection of cadavers.³ The practical dissection of the human body by medical students started in Great Britain as early as the beginning of the 15th century.⁴ "Dissection is a Royal road, which follows a pass through difficult mountains to pleasure and piece of mind."⁵ Practical dissection consolidates the knowledge in a clinically relevant way.⁶

Historical background. Owing to the tendency of biological tissues to decompose and putrefy with time, many techniques for preservation of cadavers

have evolved. Though our knowledge of conservation techniques used in the old Kingdom of ancient Egypt is limited, the analysis of clavicle fragments of the mummy of "Idu-II", Secretary General of Pinewood Trade Office (2150±50BC) has extended the history of embalming to 1,000 years earlier than previously thought.⁷ The methodology behind mummification is encompassed by the life of the King "Osiris" who brought civilization to Egypt. Ancient Egyptians believed that an intact preserved body was necessary for the soul to live forever.⁸ Unfortunately there is no written detail describing the process of mummification. To the best of our knowledge, the first written report on mummification comes from Herodotus (450 BC), a Greek traveler and historian.⁹ In formal mummification the internal organs (except heart) were removed. The body was thoroughly washed with water and aromatic solutions, dried with natron and after desiccation, remains were coated with resins and wrapped in

From the Department of Anatomy, College of Medicine, and King Khalid University Hospital, King Saud University, Riyadh, Kingdom of Saudi Arabia.

Address correspondence and reprint request to: Dr. Muhammad Saeed, Department of Anatomy, 28-KKUH College of Medicine, and King Khalid University Hospital, King Saud University, PO Box 2925 Riyadh 11461, Kingdom of Saudi Arabia. Tel. +966 (1) 4672545. Fax. +966 (1) 4671300. E-mail: shafi@ksu.edu.sa/msaeedshafi@hotmail.com

linen bandages. In the early years, the process was simple desiccation. By the Middle Kingdom, mummification had become an elaborate process and great skill being demanded from the embalmers. In the later periods, the preservation of the body became less important than application of bandages in elaborate geometric patterns.¹⁰ The bitumen, waxes, oils, resins and plant gums are known ingredients that the embalmers used in ancient times.¹¹ The 12-fold higher sodium content (4100 μ mol per gram dry weight) in Idu's clavicle measured by atomic emission spectrometry, compared with sodium analysis of bones from modern autopsies (330 μ mol/g dry weight) suggests that natron was applied directly to the skeleton. No microbial contamination of bones was detectable. The wealth of pinewood compounds and sodium in the bones support the proposal that "Idu II" had been defleshed or skeletonized at least in part before embalming. This 4,000 years old conservation has been most beneficial for preserving the functional and structural intactness of bone alkaline phosphatase.⁷ Although the Egyptologic literature does not offer any argument indicating the use of tannic acid substance for mummification, identification of methylgallate and inositols in different parts of a 40-year old body of an unknown Egyptian mummy #90001255 (100BC) from the Guimet Natural History Museum in Lyon, France, indicates the general use of vegetable tannins for mummification in ancient Egypt. Moreover different compositions of embalming mixture were used in different body parts of mummified corps.¹² Considering the mummification and refined embalming techniques that developed over the dynastic reigns, it is somewhat of a paradox that Egyptian medicine in general had a limited grasp of human anatomy.¹³ The history of preservation and preparation of anatomical specimens is inevitably linked to the history of the study of anatomy itself and the history of development of anatomy is the history of attitude of people towards dissection.⁶ Thanks to the work of Hippocrates, Celsus and Galen during 400BC to 200AD, which progressed the knowledge of the internal structure of body to an advanced stage.¹⁴ After the decline of the Roman Empire, the study of anatomy ceased to make any progress like other disciplines of Science.¹⁵ The renaissance in the science of anatomy begun with Leonardo da Vinci (1452-1519), who was the first to start systemic topographical dissections and serial sections to illustrate the structure of the body.¹⁶ Andreas Vesalius¹⁷ published his "De fabrica humani corporis" in 1543, a unique textbook of anatomy. This revival of learning was linked with the awakening of interest in natural history and founding of museums.¹⁸ These mediaeval museums consisted of bones, fossils and dried varnished viscera, having little resemblance to actual structure. Robert Boyle (1663) sought out a procedure for defying

putrefaction by preserving a little snake in spirit of wine.¹⁹ There are a few references to anatomical injections as early as the 16th century.²⁰ Embalming is destined to retard desiccation and prevent fungal attacks on cadaveric tissues. Jan Swammerdam^{19,21,22} was the first anatomist to start injecting masses in 1672 with wax and turpentine for preservation of viscera. Once the advantages of solidifying injection had been realized, many materials were tried to discover their individual merits. Guillaume Homberg was the first to realize the potential value of fusible metals.^{20,23} In the 18th century,²⁴⁻²⁶ the technique of preservation was carried to a higher degree of perfection by William Hunter (1718-1783), William Hewson (1739-74), William Cumberland Cruikshank (1739-74) and John Sheldon (1752-1806). In an unpublished paper, preserved at the Royal Society London, Joshua Brookes in 1784 wrote the first instructions for the preservation of dissecting room cadavers.²⁷ John Hunter did not confine himself to any particular type of injection.²⁸ He embalmed female bodies in 1775 for the Royal College of Surgeons,²⁹ which kept all their freshness of youth,³⁰ until the museum was bombed in 1941.³¹ Wilhelm Von Hofmann,³² Chemist to the Royal Mint in 1863 discovered the gas "Formic aldehyde". The 40% solution of this gas (Formalin) was first used as a fixative by Ferdinand Julius Cohn in 1893.²⁷ Soon the zoologists and anatomists found a suitable formula for its use as a preservative and fixative.²⁷ Formalin is an excellent fixative, which coagulates the proteins, hardens the tissues and also sterilizes them,³² but it lacks the ability to diffuse through the tissues like spirit.³³ Phenol renders the tissues sterile and protects them from fungal attack. Glycerine is frequently used to counteract the tendency of tissues to dry up during dissection and makes the tissues more pliable. Glutaraldehyde is also dependable for tissue fixation and color preservation but not frequently used for embalming, because it is expensive and more toxic. Formaldehyde remains the first choice fixative for dissecting room cadavers. It discolors the tissues and emits vapors, which are irritant to the eyes and respiratory tract. Moreover, the tissues fixed in formalin require periodic wetting to avoid drying. The irritant vapor emission quality has restricted the use of formalin-fixed specimens to gross anatomy museums and dissection halls only. Adult bodies of average build usually need 6 to 7 liter's of embalming fluid. The following composition is commonly used for injecting dissecting room cadavers: formaline-one liter, glycerine-500ml, carbolic acid-500ml and tap water - 8 liters.³⁴ The conventional method for embalming human cadavers by gravity aided perfusion through the femoral artery, has advanced to the use of peristaltic pump or an electrically operated mobile embalming unit, that offers a faster and better quality of embalming. Bisailon and Bourassa proposed a

mobile embalming unit in 1984, having flexibility of fluid flow and pressure control.³⁵ Jayavelu listed the minimum requirements of a good injector and warned about the constant danger of air embolism during embalming injection.³⁶

Plastination. Plastination is an embalming process Von Hagens³⁷ developed in 1979, which not only preserves a cadaver but also keeps it fulsome, lifelike and indefinitely antiseptic.²² The plastination technique is an extension of the formal embalming process. For plastination, the cadaver is first fixed in formalin by formal embalming procedure and dissected to display the desired topographic features. The dissected specimens are then dehydrated by freeze substitution in acetone at -25°C , which eliminates water and fat from the body tissues. The corpse is then submerged in fluid plastic that fills in all the cavities and is then hardened gradually under heat and ultraviolet light. The specimens may take 4-12 weeks to complete the process of plastination.³⁷ Thus treated cadavers can be sliced into cross-sections. Plastination is a unique method of permanent preservation in which anatomical specimens are completely impregnated with reactive polymers, silicone rubber, epoxy or polyester resin (Biodur S10/S3). The type of polymer used determines the optical properties of the specimen,³⁸ and variations of the technique are used for hollow viscera, sponge structures and brain (Figure 1).³⁹

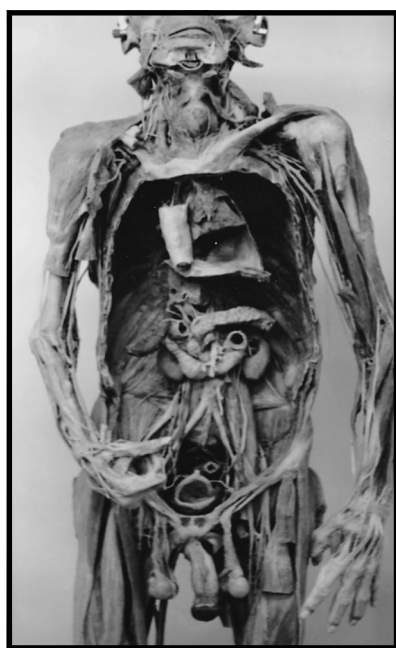


Figure 1 - Prosected and plastinated male cadaver showing ventral view of partially dissected thoracic, abdominal and pelvic cavity. Note the clarity of details of viscera, external genitalia and the limbs.

Plastinated specimens as a teaching aid in anatomy. Plastinated specimens are dry, durable, odorless and give a true to life appearance. Human plastinated specimens are today's milestone in medical education. They have become an ideal teaching tool not only in anatomy but also in pathology, obstetrics, radiology and surgery.⁴⁰ Teaching of topographic anatomy along with its clinical application in clinical years is now considered essential. Its very difficult to display formaline fixed prosected parts in the hospital wards. In these circumstances the plastinated specimens would be an ideal teaching tools in medical teaching. Human cadavers remain the best way to provide 3-dimensional pictures of anatomy to medical students. The human gross anatomy laboratory experience continues to play a major role in the objective of learning anatomical concepts and the relationships that are later applied to the understanding of clinical situations.⁴¹ The time spent on repeated reading of a textbook is less effective than the time spent thinking about the subject and visualizing a structure and its relation to the surrounding structures.⁴² Most of the time spent in a gross-anatomy course should be utilized in developing a 3-dimensional mental picture of the anatomy of a living patient.⁴³ Cottam⁴⁴ pointed out that only less than one 3rd of North American residents are adequately trained in gross anatomy. Our particular concern is the recent trend in anatomic instruction towards the digital world and away from dissection. Computers are now replacing yesterday's experienced teaching faculty.⁴⁵ Both, health care and medical education need standards based on the best long term interests of recipients. Standards in medical (anatomic) education are inextricably linked to standards for health care. Medical education is changing dramatically. Future modifications must be based on sound academic reasoning.⁴⁶ Otherwise these may provide the courts with a new attack on "educational malpractice". The diversion of medical students from cadaveric morphological study to the digital world can be avoided by providing an Anatomy Laboratory with a full range of plastinated specimens.

Acknowledgments. We thank Prof. Amonoo-Kuofi and Dr. Khalid Rida Murshid, for their generous and critical advice, Dr. Mohamed Ahmed Abdalla for Arabic translation, Dr. Muhammad Shakil Sadiq and Mr. Hanif Shahid for technical contribution and Mr. M. Moazam for his secretarial assistance.

References

1. Sinclair D. The two anatomies. *Lancet* 1975; 19: 875-878.
2. Singer C. The great Alexandrians about 300BC - 250BC. A short history of anatomy and physiology from Greeks to Harvey, the evolution of anatomy. New York: Dower Publications; 1957. p. 28-29.

3. Coupland RE, Tressider GC, Green NA. The teaching of Anatomy. Report of a conference held at the Royal College of Surgeons on 26th May 1976. *Ann R Coll Surg Engl* 1976; 58: 434-439.
4. Ellis H. Teaching in the dissecting room. *Clin Anat* 2001; 14: 149-151.
5. Lockhart RD. The art of learning anatomy. *Lancet* 1927; 27: 460.
6. Newell RLM. Follow the Royal road: The case for dissection. *Clin Anat* 1995; 8: 124-127.
7. Koller J, Baumer U, Kaup Y, Etspuler H, Weser U. Embalming was used in old Kingdom. *Nature* 1998; 391: 343-344.
8. Armstrong K. A history of God: The 4,000 year quest of Judaism, Christianity and Islam. New York: Ballantine Books; 1993. p. 1-45.
9. Putnam J. Mummy: An eye witness guide. London: Dorling Kindersley; 1993. p. 1-64.
10. Yardley M, Rutka J. Rescued from the sands of time. Interesting otologic and rhinologic findings in two ancient Egyptian mummies from the Royal Ontario Museum. *J Oto Laryngol* 1997; 26: 379-383.
11. Lucas A, Harris JR. Ancient Egyptian materials and industries. London: Histories and Mysteries of Man Ltd; 1962.
12. Mejanelle P, Bleton J, Goursaud S, Tchaplal A. Identification of phenolic acids and inositols in balms and tissues from an Egyptian mummy. *J Chromatogr* 1997; A767: 177-186.
13. Cockburn A, Barraco RA, Reyman TA, Peck WH. Autopsy of an Egyptian mummy. *Science* 1975; 187: 1155-1160.
14. Singer C. Greek biology and its relation to the rise of modern biology. In: *Studies in the history and method of science Vol. II*. New York: Arno Press; 1975. p. 1-101.
15. Singer C. Decline and fall of ancient science. In: *A history of biology to about the year 1900. A general introduction to the study of living things*. London and New York: Abelard Schuman; 1960. p. 54-78.
16. Hopstock H. Leonardo as anatomist. In: Singer C, editor. *Studies in the history and method of science, Vol. I and II*. New York: Arno Press; 1975. p. 151-191.
17. Singer C. The revival of anatomy. In: *A history of biology to about the year 1900. A general introduction to the study of living things*. London and New York: Abelard Schuman; 1960. p. 98-100.
18. Reiser SJ. Examination of the patient in the 17th and 18th centuries. In: *Medicine and the reign of technology*. London: Cambridge University Press; 1978. p. 1-22.
19. Singer C. Early museums. In: *A history of biology to about the year 1900. A general introduction to the study of living things*. London and New York: Abelard Schuman; 1960. p. 143-146.
20. Cole FJ. The history of anatomical injections. In: Singer C, editor. *Studies in the history and method of science Vol. II*. New York: Arno Press; 1975. p. 285-343.
21. Hinman F, Morison DM, Lee-Brown RK. Methods of demonstrating the circulation in general. *J Am Med Ass* 1923; 81: 177.
22. Tompsett DH. Introduction. In: *Anatomical techniques*. Edinburgh and London: E & S Livingstone; 1970. p. 93-95.
23. Homeberg G. Essais sur les injections anatomiques. *Hist de l'Academie Royale des sciences* 1702; Ann 1699: 8.
24. Knut H. The illustrated history of Surgery. London: Harold Starke; 1988. p. 152.
25. Guthrie D. Eighteenth century medicine. In: *A history of medicine*. Toronto and New York: Thomas Nelson & Sons; 1958. p. 240-244.
26. Bailey GH. William Hewson FRS (1739-1774), his life and work. *Ann Med Hist* 1923: 209.
27. Dobson J. Historical introduction. In: Tompsett DH, editor. *Anatomical techniques*. Edinburgh and London: E & S Livingstone; 1970. p. 1-3.
28. Singer C. Rise of comparative method. In: *A history of biology to about the year 1900. A general introduction to the study of living things*. London and New York: Abelard Schuman; 1960. p. 212-215.
29. Keith A. Illustrated guide to the Museum of the Royal College of Surgeons, London. London: Lincoln's Inn; 1910.
30. Keith A. Destruction of the Museum of the Royal College of Surgeons, London. *Bull Hist Med* 1941; 10: 631-632.
31. Sigerist HE. Museums of medical history, Appendix III. In: *A history of medicine. Vol I. Primitive and archaic medicine*. New York: Oxford University Press; 1955. p. 525-531.
32. Miall LM, Sharp DWA. Formaldehyde. In: *A new dictionary of chemistry 4th ed*. New York: John Wiley and Sons; 1968. p. 249.
33. Young B, Heath JW. Cell structure and function. In: *Weather's functional Histology: A textbook and colour atlas*. Toronto: Churchill Livingstone; 2000. p. 2-3.
34. Janakiram S, Balasubramanyam V, Thomas IM. A simple device for embalming cadavers. *Indian J Pathol Microbiol* 1998; 41: 39-42.
35. Bisailon A, Bourassa R. Mobile embalming unit for preparation of specimens for anatomical studies. *Anat Rec* 1984; 208: 147-148.
36. Jayavelu. Injection methods, pressure control and distribution of fluid. In: *Embalming*. London: Churchill Livingstone; 1991. p. 126-138.
37. Von Hagens G. Impregnation of soft biological specimens with thermosetting resins and elastomers. *Anat Rec* 1979; 194: 247-255.
38. Bonfante J. The anatomy of death: An exhibition of preserved cadavers in Germany is provoking fascination, skepticism and outrage. *Time*, December 15, 1997; 62.
39. Von Hagens G, Tiedemann K, Kriz W. The current potential of plastination. *Anat Embryol* 1987; 175: 411-423.
40. Al-Zuhair AGH, Butt MM, Amonoo-Kuofi HS. Plastination-A modern technique supplementing the teaching of anatomy. *Biomed Res* 1995; 6: 231-233.
41. Marks JSC. Information technology, medical education and anatomy for the 21st century. *Clin Anat* 1996; 9: 343-348.
42. Rosse C, Gaddum-Rosse P. The study of anatomy. In: *Hollinshead's textbook of anatomy*. Philadelphia: Lippincott-Raven; 1997. p. 4-5.
43. Yeager VL. Learning gross anatomy: dissection and prosection. *Clin Anat* 1996; 9: 57-59.
44. Cottam WW. Adequacy of medical school gross anatomy education as perceived by certain postgraduate residency programs and anatomy course directors. *Clin Anat* 1999; 12: 55-65.
45. Levine MG, Stempack J, Conyers G, Walters JA. Implementing and integrating computer-based activities into a problem based gross anatomy curriculum. *Clin Anat* 1999; 12: 191-198.
46. Cahill DR, Leonard RJ, Marks SC. Standards in health care and medical education. *Clin Anat* 2000; 13: 150.