VIA MEDICA

REVIEW ARTICLE

Folia Morphol.
Vol. 82, No. 3, pp. 449–456
DOI: 10.5603/FM.a2022.0055

ISSN 0015–5659
eISSN 1644–3284
journals.viamedica.pl

Thiel embalming method used for anatomy dissection as an educational tool in teaching human anatomy, in research, and in training in comparison of different methods for long term preservation

M. Rakuša, L. Kocbek Šaherl

University of Maribor, Faculty of Medicine, Institute of Anatomy, Histology, and Embryology, Maribor, Slovenia

[Received: 30 March 2022; Accepted: 24 May 2022; Early publication date: 10 June 2022]

The use of human cadavers is beneficial in teaching gross human anatomy, training, and development in medicine. Fresh-frozen cadavers initially exhibit natural colour, tenderness, and flexibility. They also present innumerable difficulties, including the requirement of freezers for storage and a few weeks' work time because of fast decay. The risk of infection is also significant. A possible choice for fresh-frozen cadavers is embalmed cadavers. The requested characteristic needed for successful embalming is acceptable long-term structural preservation of organs and tissues with minimal deformity and prevention of outward aspects. Scientists are trying to develop an ideal embalming solution to preserve the human body. Such a solution renders the flexibility of internal organs, preventing dryness, and reducing fungal or bacterial growth. Cadavers should be in a condition comparable to that of an unembalmed cadaver, and the chemicals used in the solution should not be harmful to persons during manipulation. The promising results have been obtained by the use of different embalming techniques by many faculties of medicine as a tool to enhance the teaching of anatomy to students. (Folia Morphol 2023; 82, 3: 449–456)

Key words: anatomy, embalming method, cadaver dissection, education

INTRODUCTION

Human cadaveric dissection has been used as the base teaching tool in anatomy for centuries [1, 44]. Fresh-frozen cadaver is the closest to learning anatomical structures under realistic conditions although it can be properly well-used in a very limited time [1, 44]. There are several insecurities when working with a fresh-frozen cadaver for the reason that the fresh corpse disintegrates immediately, the risk of infection is high as the bacteria multiply rapidly and further use due to freezing and thawing is no longer endorsed [31, 32]. Embalming with formalin is safe against infections with microorganisms, suitable for long-term storage, and is an inexpensive method. On the other hand, the tissue becomes more compacted over time and less comparable to the natural structures in the body. In addition, continuous inhalation of formalin in high concentrations may be harmful to health and carcinogenicity has been reported [11]. Soft-fix and flexible cadavers are formed by Thiel's method. The colour of the tissues remains natural, the cadaver is manageable and very suitable for use. In

Address for correspondence: Assist. Prof. Dr. M. Rakuša, The University of Maribor, Faculty of Medicine, Institute of Anatomy, Histology, and Embryology, Taborska ulica 8, SI-2000 Maribor, Slovenia, e-mail: mateja.rakusa@um.si

contrast, the preparation of the deceased is relatively expensive and demanding, even though the time for dissection is defined [5–9]. A saturated salt solution (continued as SSS) can also be used for embalming the dead human body. As a method, it has many advantages, including technical implementation, not having a lot of risk of infection and it is cost-effective. It seems to be adequately useful for surgical training and has characteristics for clinical training [35, 36, 63].

We made several observations as outlined in the publication describing fresh-frozen cadavers, formalin-embalmed cadavers, Thiel-embalmed cadavers, and in a SSS embalmed cadavers [35, 36]. We are convinced about the positive effects of structures due to the anatomical dissection of the Thiel-embalmed cadaver, also because we use the method by ourselves. Not only does it enhance the students' learning of anatomy, thus improves the students' long-term ability to identify anatomical structures [47].

HISTORY OF HUMAN BODY PRESERVATION

The intent to preserve the body in response to questions of a religious nature has existed since ancient times [11, 26, 27]. Different techniques were used in the early beginnings of embalming, like exenteration or the corpse being immersed for a while in an alcohol solution, plus herbs imprinted in the corpse served for preservation as well as cadavers were wrapped in waxed or tar sheets [25–27]. Ancient civilizations invented the embalming process, while for Europe it had been unprecedented for a very long time [1, 26, 27, 44, 58]. Embalming became influenced by scientific developments in medicine. Bodies were needed for dissection purposes and preservation required more refined embalming techniques [50]. The German chemist August Wilhelm von Hofman 1869 discovered and determined formaldehyde to be an excellent preservative [19, 28]. In improving the embalming method a combination of salts, chloral hydrate, and formaldehyde [42, 43] along with solutions based on alcohol, glycerine, and phenol [69] were experimented with by scientists. By modifying the original embalming procedures researchers presupposed a simple method for longer persistence of cadavers and thus its use for learning intentions [10, 12, 23, 48, 68]. A visionary scientific leader Walter Thiel [24, 29] presented 1992 an embalming method that maintains the natural look, colour, flexibility, and characteristics of a living body [26, 27, 66, 67].

THIEL'S EMBALMING METHOD

The introduction of soft fixed cadavers using the Thiel embalming method has dramatically improved the flexibility and colour retention of cadavers used for teaching anatomy [29, 40]. Intravascular Thiel's embalming technique keeps the cadaver soft to physical contact and permanent movable, all anatomical structures retain in natural colour and due to learning, comparability with the properties of living people is of paramount importance. Those typical characteristics of cadavers [40] have been suitable in fields such as thyroid surgery, echography, regional anaesthesia [20, 48] and ultrasound-guided anaesthesia [7], laparoscopy, tendon repair, flap raising, and microsurgery [68], including maxillofacial surgery. Although the insertion of dental implants is a predictable and successful method of replacement, the insertion of dental implants into the jawbone with all possible complications could first be made on embalmed corpse models [38]. Thiel-embalmed cadavers have been applicable for intubation and ventilation, suturing, biopsies. The chest radiographs of Thiel-embalmed cadavers were also described. Workshops for several medical disciplines have been arranged. Despite the many positive properties of Thiel's method, the technical process of preparing the solution is exacting and expensive. Some of the chemicals are poisonous, inflammable, explosive, extremely unhealthy, and environmentally unfriendly. The imperfection of Thiel-embalmed cadavers has been muscular disorganization and a limited time for dissection as well as noticeable histological alterations [36]. Also for learning to insert a central venous canal, Thiel-embalmed cadavers are less or even inappropriately. Other embalming methods were tested with better results. Nonetheless, Thiel's embalming method shows significant properties. There are advantages to joint and muscle flexibility and because of that, we can bend the limbs. The colour of the corpse is very similar to the physiological appearance. Due to the work and handling of the preparations, a completely reduced exposure to microorganisms has been improved so that it is safe to work against infections. Further, good flexibility and plasticity preservation in organs and tissues are remarkable characteristics as well [57, 66–68]. At autopsy, tissue and organ samples are taken for

histological examination. The embalmed cadaveric tissue is already fixed and opinions on compliance for all histological studies have been divided [54].

Many authors have repeated the original procedure since Thiel's method was introduced. And in current studies modifications, a fixative according to Thiel's formulation of solutions has been used for better fixation of cells of the central nervous system. By inserting a needle into the subarachnoid space the fixative can penetrate the tissue promptly and thus ensure the persistence of the brain and spinal cord for further research or for learning the anatomy of the central nervous system [21, 22]. Eljamel received good imaging with clear differentiation of white and grey matters in studies of Thiel-embalmed cadavers with magnetic resonance imaging. They could be relevant for practical training and microsurgical workshops for scientific investigation inside the brain or other parts of the body [18]. Thiel's method could be used for the progress in otoneurosurgery for which mechanisms of normal and pathological events are involved here [2]. Additionally, morphometric studies of anatomical muscle variations [59], insertions, perforating vessels, repairs and reinforcement of tendons, and prophylaxis were done by Thiel-embalmed cadavers. Thiel-embalmed cadavers have accelerated possibilities for extending experimental laparoscopic surgery, the establishment of new endoscopic surgical methods [33, 55], principally in urinary tract surgery [37] as well as proceeding in angiology [33, 55], thyroidectomies, cricothyroidotomies [9], liver surgery simulations, arthroplasty, artery sutures, peripheral nerve repair, flap surgeries [34], neurosurgery, and anastomosis techniques [56, 57]. In principle, they would be constructively practical in improving the efficiency of surgical techniques together with the development of various surgical techniques.

All these numerous characteristics [57] of Thiel-embalmed cadavers are very appropriate and relevant for undergraduate and graduate education, training, and specialised surgical abilities. Their complex handling is preferred from formalin-embalmed cadavers, and even fresh cadavers [7–9].

FORMALIN EMBALMING METHOD

The earliest research on using formalin solution (FAS) as an embalming agent has occurred in 1899 [53]. Not much has changed in the basic technique of formalin maintaining. FAS stands as the most frequently used embalming solution. It is an excellent tissue fixative without destroying its delicate structure [4, 53]. Assures protection against pathogenic microorganisms and prevents infection [4, 7, 11, 30]. On the contrary, tissues, and organs impregnated with formalin become even more rigorous, with the lost appearance of natural colour and with the loss of all other characteristics of living organs [53]. The smell of formalin is very strong and later high exposure, it can be irritating for the nose, eyes, skin, and airways, along with chronic toxic effects [11, 39, 51, 53].

Imaging techniques such as ultrasound and radiography in formalin-embalmed human cadavers were poorly detectable [61] and are not preferable for a detailed examination of the skeleton, body cavities, and all present pathologies in the body cavities, as well as the accumulation of gas in the intestine [4, 5, 13, 15, 16, 40].

Despite all these effects, FAS is still the most frequently in use in the Faculty of Medicine all over the world because is a good detection solution [53]. The influence of re-evaluation of formalin concentration, appropriate ventilation, and assessment of working practices in the dissecting rooms at the Anatomy Departments provided FAS as commonly used as a preservative [53].

SATURATED SALT SOLUTION EMBALMING METHOD

Cadavers were also excellently preserved by using the SSS embalming method and might become an alternate method for embalming. The salt solution was described as readily available, uncomplicated, and inexpensive. Cadavers embalmed by the SSS method had a minimal structural deformity, their colours remained natural, and the blood remained liquefied. The X-ray and ultrasound images were also used in cadavers embalmed by the SSS method where very intense fluid was observed in pericardial, pleuroperitoneal, and peritoneal spaces. Central venous catheterisation could be inserted in the SSS-embalmed cadavers too. The indicated cadavers were presentable for laparoscopic and microvascular surgery, pulmonary ventilation, auto suture-stapling material, and echo-guided peripheral nerve block. Lungs and intestines could be incised with an electrosurgical knife and closed using an auto suture-stapling device. Softness and mobility of tissues and joints are important aspects found in embalmed cadavers. But most excellent properties have been described and tested with Thiel-embalmed cadavers, compared to

embalmed cadavers in salt solutions. Those cadavers have been considered as being too consolidated to perform surgical practice [35, 36, 63].

FRESH CADAVERS

Fresh-frozen cadavers have been repeatedly described as suitable in many studies for their most natural appearance and consistency. Even though the fresh cadavers were considered as being not applicative for usual procedures [50, 52, 60, 62, 64]. They present innumerable difficulties, including the specification for adequate cooling space and time-delayed work because of fast decay. The risk of infection is also significant [3, 15–17, 30].

THE USE OF HUMAN BODIES IN EDUCATIONAL SETTINGS AND FUTURE DIRECTION

According to the literature, the appropriate preservation of the cadaver is essential [1, 44].

The embalmment method was developed as a response to teaching anatomy, as a valuable educational tool [1, 44] to ensure a well-preserved cadaver, and to prevent destruction, decomposition, and contamination [4]. The dilemma in a well-developed new method for embalming cadavers is only funding involved in establishing [1, 44].

In terms of visual and tactile assessment, regarding its usefulness in teaching undergraduate students, postgraduate students, and surgical specialists, many medical educational institutions have included in the curriculum plastic anatomy models, three-dimensional (3D) atlases, and virtual human models [1, 44]. According to students, it is important to note that only a traditional method like cadaveric dissection includes the concepts of gross anatomy, structural details, and anatomical variations. The limited availability of corpses, location for storage, preparation, or dissection of the cadaverous parts, and the ascending development of modern technologies, like anatomical models and 3D visual implements, are taking the place of human cadavers in the teaching of human anatomy [1, 44].

Feedback from students undertaken through questionnaires or evaluation forms presented with studies by authors Alamneh [1] and Kalthur et al. [44] illustrated the impact of the usefulness and importance of dissection in today's teaching of anatomy. Two-thirds of students realised the relevance of anatomy and agreed that adequate knowledge and understanding of anatomy can only be acquired when medical students are exposed to the tissues and structures within the body. Those students felt confident with the cadaveric dissection. In addition, one-third of students perceived the role of the tissue dissection module as unprogressive and inapplicable. A few had a negative attitude towards death, and emotional trauma [1, 44]. A similar response has been observed from our students.

Students are technologically sufficiently educated and skilled in obtaining all information, including in the field of anatomy. But all of the above is not enough for the acquired knowledge of human anatomy or for objectively learning and developing surgical skills. Anatomy is one of the most prominent and necessary subjects of medical and nursing education. Dissection has been an important part of medical education as the complete preservation of the body contributes to learning not only the theoretical concepts of structure, framing, and the relationship between body parts, but visualization of the basic components of the body might help detect tissue characteristics or any other important clinical benefits [1, 44]. Withal, training on cadavers is important in appropriate training to evaluate skills in surgical experience and in diagnostic as well as therapeutic endoscopic skills [1, 44]. Practice and work on the appearance of the cadavers according to the tissue quality, colour and consistency have been recognized as excellent compared to real-life patients. The four preservation methods reviewed so far with different advantages and disadvantages are certainly no less useful in comparison. Each technique in microsurgery, endoscopy, laparoscopic and arthroscopic surgery, and interventional radiology is consistent with special skills programmes, and diagnostic and therapeutic interventions. According to the literature Thiel-embalmed cadavers are more eligible than formalin-embalmed cadavers or fresh-frozen cadavers [40]. Thiel embalmed cadavers allow the muscular and connective tissue to retain most of its premortem texture and tone [45, 46]. Most cadavers are used for laparoscopic procedures and more realistic representations of the movement and function of the musculoskeletal system [1, 44]. Thiel-embalmed cadavers are applied in workshops on ultrasound-guided regional anaesthesia [45, 46], thoracic surgery, abdominal surgery, urology, arthroscopy, and other fields of surgery, together with magnetic resonance imaging-guided procedures involving vascular devices and focused ultrasound [7]. They have been

used to evaluate new ultrasound-guided regional anaesthesia techniques and equipment, laparoscopic equipment, laryngoscopes, retractors, and hip and shoulder prosthesis. Thiel-embalmed cadavers are becoming useful in making imaging diagnoses and performing guided therapeutic procedures [7, 18]. Farther, dental surgeons have been testing inferior alveolar nerve blocks and extractions [38, 57].

The visualisation and manipulation of cadavers remain the gold standard to teach anatomy and are suitable for extension activities in the medical faculty, especially in surgical and clinical training [1, 44]. Focusing on the values of learning the human anatomy through the active voluntary body donation programme in the medical curriculum, awareness of the ethical and humanistic values of cadaveric dissection must be carried out respectfully. Because the use of the cadavers is an assessment of knowledge and practice, ethical consideration with profound respect for the deceased person among graduate and undergraduate students, ultimately for all medical professionals is expected undoubtedly [1, 41, 44, 65].

We will continue further work at our institute with the Thiel embalming method as we are very satisfied with the method. Only for one-day or short-term workshops, where the corpses would be used once, we are considering another method. For more assessment of appropriateness, the parallel use of cadavers, each in another solution of embalming, and for the same learning purposes allow our further evaluation of the advantages and disadvantages of all methods described above. According to the results in the articles, the use of SSS for embalming has similar positive properties as Thiel's method does and the use of these cadavers may be perfectly suitable in anatomy education [35, 36], for postgraduate students in training to evaluate their skills, and also for surgeons who are constantly being trained in their work in general surgeries on soft tissues, laparoscopic surgical procedures and a surgical subspecialty of the vascular system, minimally-invasive catheter procedures, and plastic and reconstructive surgery. The use of cadavers is effective and helps surgeons to gain technical competence before performing any procedures on patients. The fresh-frozen and formalin methods are also suitable but perhaps only for short-term learning interventions such as emergency procedures or with reduced exposure to practical anatomy in education.

For teaching anatomy, where students work and learn on cadavers by themselves, cadavers must ensure competent tissue properties, durability, and long-standing perseverance. Additionally, methods must ensure that the tissues of the cadavers maintain a similar appearance to their premortem condition, and provide good conditions for the cadavers for a longer period. All cadavers will differ from living patients but these differences allow re-use across a range of procedures.

CONCLUSIONS

We focused on the analysis of the potential effects of four embalming methods in terms to choose a method that can be very useful for learning anatomy and for a variety of learning events for academic and teaching employees and workshops for medical students. Regarding the procedure, Thiel's method is favoured and pleasantly evaluated among teachers, students, surgeons, and instructors. It has brought benefits to the study, decreases the level of toxicity, and offers long-term preservation that combines flexible tissues and a good cosmetic appearance similar to *in vivo* conditions. Compared with other methods, general surgeries were performed mostly with SSS embalmed cadavers [26], formalin has shown superior bactericidal and bacteriostatic properties, and without destroying tissue's delicate structure [13]. Thiel's method is increasingly widely known [67], it is overpriced, and complex components are required, while SSS is simpler and low-priced but its use in anatomy education has been limited [4, 5].

Teaching practices in anatomy education are based on either demonstrating dissected specimens or human cadaveric dissection individually [1, 14, 44]. The most frequently used was formaldehyde and since 1992 use of the Thiel embalming method has been implemented for the long-term preservation of cadavers, with a minimum and non-toxic amount of formaldehyde [14]. It seemed therefore to preserve body with low health risk and suitable for the palpable experience. It cannot be harmful to the students and its use is ethical. Soft consistency allows students to perform dissection practices in conditions very similar to those they would present *in vivo*.

Dissection should be reinforced and enriched in undergraduate medical school, considering that learning basic anatomy by using human cadavers is still the most important learning tool for educational anatomy as well as for understanding and respecting ethical principles. Only in this way can students study the topographic and regional anatomy, the continu-

ous veins and nerves, the lymphatic system, and all variations that are not so rare. Commonly, students study anatomy from atlases, books, and lecture notes although the experience of the general aspects of the dimensional relationships in the body even modern and contemporary technology cannot replace. As a part of good practices in the context of human dissection, medical students can observe these details of anatomical structures of the body and the reciprocal relationships between body parts [1, 44].

The current study has some limitations. It is based on our opinion and hence does not provide objective data on tissue properties used with the other technique. Our experience is currently based on Thiel-embalmed cadavers. And formaldehyde is also used to store organs. The experience of teachers, researchers as well as students, is good so far.

Each embalming method has advantages and disadvantages for different fields of study and education, all of which are influenced by working conditions, finances, suitable space, and also by the interest of employees and students. Due to the many advantages, and good responses from students, teachers, surgeons, and technicians, we will continue to use Thiel's method and also improve it for academic and didactic purposes. And at the same time known advantages of other methods, especially when it comes to storing and using the cadavers for a short-term preservation period or use in surgical training programmes.

Through further research to assess the knowledge, it is substantial to evaluate concepts of studying anatomy through whole-body dissection accessible to students, expose students and all medical professionals to ideas on the point of the regular use of human cadavers for learning and training purposes still rely on cadavers, and how valuable it is to identify disease sites that they might otherwise not have come into contact with [1, 41, 44].

Dissection has been an important part of medical education and still contributes positively to teaching purposes at many medical faculty. It requires fundamental educational, moral, and ethical values and should be strictly within the directives of medical institutions.

Acknowledgements

The authors of this paper would like to thank those individuals who so kindly choose to donate their bodies and additionally express our sincere gratitude through an honourable decision in agreement with Iwanaga et al. [41].

Conflict of interest: None declared

REFERENCES

1. Alamneh Y. Knowledge and attitude towards ethical cadaver dissection among medical and health sciences students, 1997–2020: A systematic review and meta-analysis. Transl Res Anat. 2021; 25: 100149, doi: 10.1016/j.tria.2021.100149.
2. Alberty J, Filler TJ, Schmäl F, et al. [Thiel method fixed cadaver ears. A new procedure for graduate and continuing education in middle ear surgery]. HNO. 2002; 50(8): 739–742, doi: 10.1007/s00106-001-0601-9, indexed in Pubmed: 12243029.
3. Anderson SD. Practical light embalming technique for use in the surgical fresh tissue dissection laboratory. Clin Anat. 2006; 19(1): 8–11, doi: 10.1002/ca.20216, indexed in Pubmed: 16287109.
4. Balta JY, Cronin M, Cryan JF, et al. Human preservation techniques in anatomy: A 21st century medical education perspective. Clin Anat. 2015; 28(6): 725–734, doi: 10.1002/ca.22585, indexed in Pubmed: 26118424.
5. Balta JY, Lamb C, Soames RW. A pilot study comparing the use of Thiel- and formalin-embalmed cadavers in the teaching of human anatomy. Anat Sci Educ. 2015; 8(1): 86–91, doi: 10.1002/ase.1470, indexed in Pubmed: 24996059.
6. Benkhadra M, Bouchot A, Gérard J, et al. Flexibility of Thiel's embalmed cadavers: the explanation is probably in the muscles. Surg Radiol Anat. 2011; 33(4): 365–368, doi: 10.1007/s00276-010-0703-8, indexed in Pubmed: 20632174.
7. Benkhadra M, Faust A, Ladoire S, et al. Comparison of fresh and Thiel's embalmed cadavers according to the suitability for ultrasound-guided regional anesthesia of the cervical region. Surg Radiol Anat. 2009; 31(7): 531–535, doi: 10.1007/s00276-009-0477-z, indexed in Pubmed: 19225711.
8. Benkhadra M, Gérard J, Genelot D, et al. Is Thiel's embalming method widely known? A world survey about its use. Surg Radiol Anat. 2011; 33(4): 359–363, doi: 10.1007/s00276-010-0705-6, indexed in Pubmed: 20665059.
9. Benkhadra M, Lenfant F, Nemetz W, et al. A comparison of two emergency cricothyroidotomy kits in human cadavers. Anesth Analg. 2008; 106(1): 182–185, doi: 10.1213/01.ane.0000296457.55791.34, indexed in Pubmed: 18165576.
10. Bradbury SA, Hoshino K. An improved embalming procedure for long-lasting preservation of the cadaver for anatomical study. Acta Anat (Basel). 1978; 101(2): 97–103, doi: 10.1159/000144954, indexed in Pubmed: 565573.
11. Brenner E. Human body preservation: old and new techniques. J Anat. 2014; 224(3): 316–344, doi: 10.1111/joa.12160, indexed in Pubmed: 24438435.
12. Coleman R, Kogan I. An improved low-formaldehyde embalming fluid to preserve cadavers for anatomy teaching. J Anat. 1998; 192(Pt 3): 443–446, doi: 10.1046/j.1469-7580.1998.19230443.x, indexed in Pubmed: 9688512.

13. Coskey A, Gest TR. Effectiveness of various methods of formaldehyde neutralization using monoethanolamine. Clin Anat. 2015; 28(4): 449–454, doi: 10.1002/ca.22534, indexed in Pubmed: 25832967.
14. Denis Rodriguez E. Thiel soft-fix method for long term preservation. Rev Mex Med Forense. 2017; 3(2): 91–98.
15. Eisma R, Lamb C, Soames RW. From formalin to Thiel embalming: What changes? One anatomy department's experiences. Clin Anat. 2013; 26(5): 564–571, doi: 10.1002/ca.22222, indexed in Pubmed: 23408386.
16. Eisma R, Mahendran S, Majumdar S, et al. A comparison of Thiel and formalin embalmed cadavers for thyroid surgery training. Surgeon. 2011; 9(3): 142–146, doi: 10.1016/j.surge.2010.09.001, indexed in Pubmed: 21550519.
17. Eisma R, Wilkinson T. From "silent teachers" to models. PLoS Biol. 2014; 12(10): e1001971, doi: 10.1371/journal.pbio.1001971, indexed in Pubmed: 25333490.
18. Eljamel S, Volovick A, Saliev T, et al. Evaluation of Thiel cadaveric model for MRI-guided stereotactic procedures in neurosurgery. Surg Neurol Int. 2014; 5(Suppl 8): S404–S409, doi: 10.4103/2152-7806.140199, indexed in Pubmed: 25289170.
19. Ezugworie J, Anibeze C, Ozoemena F. Trends in the development of embalming methods. Int J Altern Med. 2009; 7(2), doi: 10.5580/29b.
20. Feigl G, Anderhuber F, Schwarz G, et al. [Training methods for regional anaesthesia. Evaluation and comparison]. Anaesthesist. 2007; 56(5): 437–443, doi: 10.1007/s00101-007-1149-1, indexed in Pubmed: 17285320.
21. Feigl G, Fuchs A, Gries M, et al. A supraomohyoidal plexus block designed to avoid complications. Surg Radiol Anat. 2006; 28(4): 403–408, doi: 10.1007/s00276-006-0113-0, indexed in Pubmed: 16680393.
22. Feigl GC, Fasel JH, Anderhuber F, et al. Superior vestibular neurectomy: a novel transmeatal approach for a denervation of the superior and lateral semicircular canals. Otol Neurotol. 2009; 30(5): 586–591, doi: 10.1097/MAO.0b013e3181ab9164, indexed in Pubmed: 19574943.
23. Frewein J, Steinmann W, Müller U. [Experiences with reduced formalin fixation of specimens and formalin-free preservation of anatomic samples]. Anat Histol Embryol. 1987; 16(3): 250–253, indexed in Pubmed: 3326428.
24. Fürstner A, List B, Ritter T, et al. Walter Thiel (1949-2019). Angew Chem Int Ed Engl. 2020; 59(4): 1382–1383, doi: 10.1002/anie.201915463, indexed in Pubmed: 31917510.
25. Fylaktou A, Haidopoulou K, Goutaki M, et al. Measles and mumps immunity in Northern Greece, 2004-2007. Euro Surveill. 2008; 13(16): 18841, indexed in Pubmed: 18768118.
26. Ghosh SK. Human cadaveric dissection: a historical account from ancient Greece to the modern era. Anat Cell Biol. 2015; 48(3): 153–169, doi: 10.5115/acb.2015.48.3.153, indexed in Pubmed: 26417475.
27. Ghosh SK. Paying respect to human cadavers: We owe this to the first teacher in anatomy. Ann Anat. 2017; 211: 129–134, doi: 10.1016/j.aanat.2017.02.004, indexed in Pubmed: 28279760.
28. Grönroos H. Zusammenstellung der üblichen Conservierungsmethoden für Prä-pariersaalzwecke. Anat Anz. 1898; 15: 61–84.
29. Hachabizwa C, Banda M, Hainza J, et al. Cadaveric embalming using a modified Thiel method as an alternative to the formalin method. Anat J Afr. 2020; 9(2): 1797–1806, doi: 10.4314/aja.v9i2.199945.
30. Hammer N, Löffler S, Bechmann I, et al. Comparison of modified Thiel embalming and ethanol-glycerin fixation in an anatomy environment: Potentials and limitations of two complementary techniques. Anat Sci Educ. 2015; 8(1): 74––85, doi: 10.1002/ase.1450, indexed in Pubmed: 24706536.
31. Hammer N, Löffler S, Feja C, et al. Ethanol-glycerin fixation with thymol conservation: a potential alternative to formaldehyde and phenol embalming. Anat Sci Educ. 2012; 5(4): 225–233, doi: 10.1002/ase.1270, indexed in Pubmed: 22434588.
32. Hammer N, Schröder C, Schleifenbaum S. On the suitability of Thiel-fixed samples for biomechanical purposes: Critical considerations on the articles of Liao et al. "Elastic Properties of Thiel-Embalmed Human Ankle Tendon and Ligament" and Verstraete et al. "Impact of Drying and Thiel Embalming on Mechanical Properties of Achilles Tendons". Clin Anat. 2016; 29(4): 424–425, doi: 10.1002/ca.22679, indexed in Pubmed: 26679099.
33. Hassan S, Eisma R, Harry LE. Surgical training of anastomotic technique using Thiel cadavers. J Plast Reconstr Aesthet Surg. 2014; 67(10): e250–e251, doi: 10.1016/j.bjps.2014.06.016, indexed in Pubmed: 25034316.
34. Hassan S, Eisma R, Soames R, et al. Raising of microvascular flaps using the Thiel cadaveric model. J Plast Reconstr Aesthet Surg. 2014; 67(4): e107–e108, doi: 10.1016/j.bjps.2013.12.003, indexed in Pubmed: 24365567.
35. Hayashi S, Homma H, Naito M, et al. Saturated salt solution method: a useful cadaver embalming for surgical skills training. Medicine (Baltimore). 2014; 93(27): e196, doi: 10.1097/MD.0000000000000196, indexed in Pubmed: 25501070.
36. Hayashi S, Naito M, Kawata S, et al. History and future of human cadaver preservation for surgical training: from formalin to saturated salt solution method. Anat Sci Int. 2016; 91(1): 1–7, doi: 10.1007/s12565-015-0299-5, indexed in Pubmed: 26670696.
37. Healy SE, Rai BP, Biyani CS, et al. Thiel embalming method for cadaver preservation: a review of new training model for urologic skills training. Urology. 2015; 85(3): 499–504, doi: 10.1016/j.urology.2014.11.009, indexed in Pubmed: 25582818.
38. Hölzle F, Franz EP, Lehmbrock J, et al. Thiel embalming technique: a valuable method for teaching oral surgery and implantology. Clin Implant Dent Relat Res. 2012; 14(1): 121–126, doi: 10.1111/j.1708-8208.2009.00230.x, indexed in Pubmed: 19673955.
39. Hubbell DS, Dwornik JJ, Alway SE, et al. Teaching gross anatomy using living tissue. Clin Anat. 2002; 15(2): 157–159, doi: 10.1002/ca.1113, indexed in Pubmed: 11877797.
40. Hunter A, Eisma R, Lamb C. Thiel embalming fluid: a new way to revive formalin-fixed cadaveric specimens. Clin Anat. 2014; 27(6): 853–855, doi: 10.1002/ca.22392, indexed in Pubmed: 24639210.
41. Iwanaga J, Singh V, Ohtsuka A, et al. Acknowledging the use of human cadaveric tissues in research papers: Recommendations from anatomical journal editors. Clin Anat. 2021; 34(1): 2–4, doi: 10.1002/ca.23671, indexed in Pubmed: 32808702.

42. Jores L. Die Conservirung anatomischer Praparate in Blutfarbe mittelst Formalin. Zbl Path Jena. 1896; 7: 134.
43. Jores L. Ueber eine verbesserte Methode der Konservierung anatomischer. Objekte Münchn Med Wschr. 1913; 60: 976.
44. Kalthur S, Pandey A, Prabhath S. Benefits and pitfalls of learning anatomy using the dissection module in an indian medical school: A millennial Learner's perspective. Transl Res Anat. 2022; 26: 100159, doi: 10.1016/j.tria.2021.100159.
45. Karakitsios I, Bobeica M, Saliev T, et al. Thermometry during MR-guided focused ultrasound in a preclinical model based on Thiel embalmed tissue. Minim Invasive Ther Allied Technol. 2014; 23(2): 120–126, doi: 10.3109/13645706.2013.839950, indexed in Pubmed: 24079349.
46. Karakitsios I, Dogadkin O, Le N, et al. Measurement of proton resonance frequency shift coefficient during MR-guided focused ultrasound on Thiel embalmed tissue. Magn Reson Med. 2015; 74(1): 260–265, doi: 10.1002/mrm.25378, indexed in Pubmed: 25056821.
47. Kocbek Šaherl L, Rakuša M. Thiel's embalming method: review of the literature and our institute's experience. Acta Medico-Biotechnica. 2021; 10(2): 34–42, doi: 10.18690/actabiomed.152.
48. Lirk P, Colvin JM, Biebl M, et al. [Evaluation of a cadaver workshop for education in regional anesthesia]. Anaesthesist. 2005; 54(4): 327–332, doi: 10.1007/s00101-005-0811-8, indexed in Pubmed: 15711813.
49. Logan BM. The long-term preservation of whole human cadavers destined for anatomical study. Ann Royal Coll Surg Engl. 1983; 65: 333.
50. Macchi V, Munari PF, Brizzi E, et al. Workshop in clinical anatomy for residents in gynecology and obstetrics. Clin Anat. 2003; 16(5): 440–447, doi: 10.1002/ca.10176, indexed in Pubmed: 12903067.
51. Mayer RG. Embalming: History, Theory, and Practise. New York 2012.
52. Mitchell EL, Sevdalis N, Arora S, et al. A fresh cadaver laboratory to conceptualize troublesome anatomic relationships in vascular surgery. J Vasc Surg. 2012; 55(4): 1187–1194, doi: 10.1016/j.jvs.2011.09.098, indexed in Pubmed: 22209607.
53. Musiał A, Gryglewski RW, Kielczewski S, et al. Formalin use in anatomical and histological science in the 19th and 20th centuries. Folia Med Cracov. 2016; 56(3): 31–40, indexed in Pubmed: 28275269.
54. Nicholson HD, Samalia L, Gould M, et al. A comparison of different embalming fluids on the quality of histological preservation in human cadavers. Eur J Morphol. 2005; 42(4-5): 178–184, doi: 10.1080/09243860500473306, indexed in Pubmed: 16982474.
55. Odobescu A, Moubayed SP, Harris PG, et al. A new microsurgical research model using Thiel-embalmed arteries and comparison of two suture techniques. J Plast Reconstr Aesthet Surg. 2014; 67(3): 389–395, doi: 10.1016/j.bjps.2013.12.026, indexed in Pubmed: 24507964.
56. Okada R, Tsunoda A, Momiyama N, et al. [Thiel's method of embalming and its usefulness in surgical assessments]. Nihon Jibiinkoka Gakkai Kaiho. 2012; 115(8): 791–794, doi: 10.3950/jibiinkoka.115.791, indexed in Pubmed: 23016272.
57. Ottone N, Vargas C, Fuentes R, et al. Walter Thiel's embalming method: review of solutions and applications in different fields of biomedical research. Int J Morphol. 2016; 34(4): 1442–1454, doi: 10.4067/s0717-95022016000400044.
58. Papageorgopoulou C, Xirotiris NI, Iten PX, et al. Indications of embalming in Roman Greece by physical, chemical and histological analysis. J Arch Sci. 2009; 36(1): 35–42, doi: 10.1016/j.jas.2008.07.003.
59. Pichler W, Tesch NP, Grechenig W, et al. Anatomic variations of the musculotendinous junction of the soleus muscle and its clinical implications. Clin Anat. 2007; 20(4): 444–447, doi: 10.1002/ca.20421, indexed in Pubmed: 17022026.
60. Reed AB, Crafton C, Giglia JS, et al. Back to basics: use of fresh cadavers in vascular surgery training. Surgery. 2009; 146(4): 757–762, doi: 10.1016/j.surg.2009.06.048, indexed in Pubmed: 19789036.
61. Schramek GG, Stoevesandt D, Reising A, et al. Imaging in anatomy: a comparison of imaging techniques in embalmed human cadavers. BMC Med Educ. 2013; 13: 143, doi: 10.1186/1472-6920-13-143, indexed in Pubmed: 24156510.
62. Sharma M, Horgan A. Comparison of fresh-frozen cadaver and high-fidelity virtual reality simulator as methods of laparoscopic training. World J Surg. 2012; 36(8): 1732–1737, doi: 10.1007/s00268-012-1564-6, indexed in Pubmed: 22484566.
63. Shirai T, Hayashi S, Itoh M. Experience of raising flaps using cadavers embalmed by saturated salt solution method. Plast Reconstr Surg Glob Open. 2015; 3(10): e543, doi: 10.1097/GOX.0000000000000523, indexed in Pubmed: 26579349.
64. Shiwani MH. Fresh frozen cadaver: a model for laparoscopic surgery training. J Coll of Physicians Surg Pak. 2010; 20(7): 425–426, indexed in Pubmed: 20642938.
65. Souza A, Kotian SR, Pandey AK, et al. Cadaver as a first teacher: a module to learn the ethics and values of cadaveric dissection. J Taibah Univ Med Sci. 2020; 15(2): 94–101, doi: 10.1016/j.jtumed.2020.03.002, indexed in Pubmed: 32368204.
66. Thiel W. Die Konservierung ganzer Leichen in natürlichen Farben. Ann Anat. 1992; 174(3): 185–195, doi: 10.1016/s0940-9602(11)80346-8.
67. Thiel W. Ergänzung für die Konservierung ganzer Leichen nach W. Thiel. Ann Anat. 2002; 184(3): 267–269, doi: 10.1016/s0940-9602(02)80121-2.
68. Wolff KD, Kesting M, Mücke T, et al. Thiel embalming technique: a valuable method for microvascular exercise and teaching of flap raising. Microsurgery. 2008; 28(4): 273–278, doi: 10.1002/micr.20484, indexed in Pubmed: 18383351.
69. Woodburne RT, Lawrence CA. An improved embalming fluid formula. Anat Rec. 1952; 114(3): 507–514, doi: 10.1002/ar.1091140309, indexed in Pubmed: 12996887.