Thielova metoda balzamiranja teles: pregled literature in izkušnje našega inštituta

Thiel's embalming method: review of the literature and our institute's experience

Avtor / Author

Lidija Kocbek, Mateja Rakuša

Ustanova / Institute

Univerza v Mariboru, Medicinska fakulteta, Inštitut za anatomijo, histologijo in embriologijo, Maribor

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

Ključne besede:
balzamiranje, kadaver, anatomija, Thielova metoda, kirurško usposabljanje

Key words:
embalming, cadaver, anatomy, Thiel method, surgical training

Članek prispel / Received
27. 6. 2017
Članek sprejet / Accepted
3. 8. 2017

Naslov za dopisovanje / Correspondence
asist. dr. Lidija Kocbek
Univerza v Mariboru, Medicinska fakulteta, Inštitut za anatomijo, histologijo in embriologijo, Taborska ulica 8 2000 Maribor
Telefon +386 2 23 45 861
E–pošta: lidija.kocbek@um.si

Izvleček

Namen: *V prispevku želimo predstaviti eno najbolj raziskanih metod balzamiranja teles, Thielovo metodo, in lastne 9 letne izkušnje ter jih primerjati z literaturo.*
Metode: *Thielova metoda balzamiranja teles je zasnovana na intravaskularni aplikaciji vodne raztopine različnih kemikalij, kot so monopropilen glikol, amonijev nitrat, kalijev nitrat, natrijev sulfit, borova kislina, klorokrezol, formaldehid, etanol in morfolin. Začetni perfuziji preko karotidne in femoralne arterije sledi potopitev teles v bazen z raztopino za balzamiranje za najmanj štiri do šest mesecev. Po tem času se telesa hrani v plastičnih vrečah v hladilniku in se jih lahko uporablja več mesecev ali let.*
Rezultati: *Od leta 2008 smo po Thielovi metodi uspešno balzmanirali 16 teles. Zaradi koristnih lastnosti, ki jih metoda nudi, so postala telesa balzamirana po Thielovi metodi pomemben del v našem izobraževanju in raziskova-*

Abstract

Purpose: *We aimed to present one of the best researched methods of cadaver preservation, Thiel's method, and share our own 9–year experience in comparison with that of the literature.*
Methods: *Thiel's embalming method uses intravascular injection of a solution combined of several chemicals, such as water–based mixtures of monopropylene glycol, ammonium nitrate, potassium nitrate, sodium sulfite, boric acid, chlorocresol, formaldehyde, ethanol, and morpholine. Initial perfusion via the carotid and femoral arteries is followed by immersion in a cadaver storage basin in embalming solution for at least 4–6 months. After this, cadavers are stored in plastic bags in refrigerators and are used for months to years.*
Results: *Since 2008, we have successfully embalmed 16 cadavers using Thiel's method. Due to the beneficial characteristics of this method, Thiel's embalmed cadavers have become an important part of our education and*

nju. Kjub manjšim začetnim tehničnim težavam, smo uspeli metodo nadgraditi tako, da smo zagotovili boljšo dolgotrajno obstojnost teles.

Zaključek: *Telesa balzamirana z metodo po Thielu so podobna z živimi in služijo kot primeren model za poučevanje in raziskovanje.*

research. Despite initial technical difficulties, we managed to upgrade the method and assure better long–lasting preservation.

Conclusions: *Thiel embalmed cadavers resemble realistic living bodies and serve as an appropriate model for teaching and research.*

INTRODUCTION

Thiel's embalming method

In 1992, Walter Thiel from the Medical University of Graz, Austria, published his embalming technique on a total of 977 complete cadavers over a period of 30 years. Different solutions were first tested in vitro on fresh beef, to observe preservation of color and flexibility and the most suitable application for injections (1). The embalming solution is composed of water, monopropylene glycol, and strong oxidizing salts for fixation, such as ammonium nitrate, potassium nitrate, and sodium sulfite, as well as addition of bactericidal/antifungal agents (Tables 1, 2). Boric acid is added for disinfection and propylene glycol for preservation of tissue plasticity, with a minimal percentage of formalin concentration that adds antiseptic features (2, 3). The terminal concentration of formaldehyde is less than 0.8% (2). Low concentrations of formaldehyde, chlorocresol, and morpholine reduce health and environmental risks (1, 4, 5). Oxidation and high salt concentrations are responsible for protein denaturation (4). The effect of boric acid on muscle protein fragmentation results in flexibility (6). Ammonium nitrate, potassium nitrate, and sodium sulfite absorb the water in the tissues; muscles form nitrosomyoglobin after reaction with the nitrates, that result in a reddish colour of the muscles. Haptic features of the tissues are due to the action of ethylene glycol (3). This method preserves color, flexibility, and joint mobility without stiffness and with tissue plasticity and elasticity, and is therefore superior to formalin, especially when teaching the musculoskeletal system. The soft–fix embalming method has one major drawback in the fixation of thoracic and abdominal organs; however, skin and superficial fascial removal is therefore easier and faster, and some areas can be visualized with only blunt dissection (7). The peritoneal cavity can be inflated for laparoscopic procedures and the lungs ventilated (2). Inflated lungs result in high quality chest radiographs. Good echogenicity is accelerated by amperfusion solution of about 15 L

Table 1. *Ingredients for Thiel's basic solution I and II.*

Basic solution I 1998		Basic solution II 1998 (chlorocresol solution)	
Hot tap water	100	Monopropylene glycol	10
Boric acid	3	4–chloro–3–metylphenol	1
Monopropylene glycol	30		
Ammonium nitrate	20		
Potassium nitrate	5		

Units for liquid chemicals are given in mililiters, and for solid chemicals in grams. 1 mL=1 g.

Table 2. *Ingredients for perfusion solution.*

Cadavers perfusion solution 2001	
Basic solution I 1998	12 000
Basic solution II 1998	500
Sodium sulfite	600
Morpholine	450
Formaldehyde	500
Ethanol	2000

Units for liquid chemicals are given in mililiters, and for solid chemicals in grams. 1 mL=1 g.

and the molecular particularity of the chemicals (8). Ultrasound images of the heart, liver, and kidneys are clear (6). This method also allows for easier identification of more difficult structures such as parathyroid glands (9). Cadavers simulate live models, without rigor mortis and coagulation of blood in the vessels (2). The vessels maintain integrity in all three vessel layers (3). Distal mummification and desquamation of the epidermis occurs (2).

The cadavers are perfused with a solution that represents approximately one qurater of its weight,; therefore, the concentration of the solution is sufficient to stop bacterial decomposition as well as to kill HIV (3). Bacteriologic tests have validated its disinfection effect; no mold growth has been noticed on the specimen (1, 2).

From a technical perspective, this method is expensive, time intensive, and difficult to implement. Chemicals are toxic, flammable, explosive, noxious, and environmentally unsafe (10). While the main drawback of the technique is high cost (material, chemical products), costs can be distributed between a large number of users considering the fact that one cadaver can be used several times for different purposes (teaching, courses, research projects) (7, 10). The only method that is effective and comparable to Thiel's method is embalmment with saturated salts (6).

Clinical application of Thiel's method

Training on ideally embalmed human cadavers is essential for surgical performance, especially for difficult and infrequent procedures (12). Different fields of medicine rely on Thiel embalmed cadavers; workshops on cadavers have become a way to enchance technical skills and performance in higher surgical training (13). Many studies has been conducted on Thiel embalmed cadavers with clinical applications in reconstructive surgery, repair and reinforcement of tendons, and prophylaxis (3). The flexibility of the cadavers creates conditions for use in teaching anatomy to undergraduates, research, and surgical training techniques such as minimally invasive procedures, interventional radiology procedures, intubation, ventilation, ultrasound–guided regional anesthesia, suturing, biopsies, and endoscopies (3, 14, 15).

The gold standard for a variety of basic and advanced procedures such as gallbladder, bariatric, antireflux, colorectal, and hernia surgery is the laparoscopic approach (16). Thiel embalmed cadavers have been used for laparoscopic bariatric surgery, colorectal surgery, surgical gastroenterology, arthroscopy, thoracic surgery, and endoscopic gynecology. Endoscopical endobronchial techniques and bronchoscopy for investigation and treatment can be done (2). Thiel cadavers exhibit features such as correct positioning, preparation of the operative field, installation and setup of technical equipment and the surgical team, correct trocar placement, and pneumoperitoneum that cannot be simulated on the virtual computer models (16).

Thiel embalmed cadavers provide ideal tissue characteristics for transanal, transrectal, and transvaginal procedures for natural orifice transluminal endoscopic surgery, such as total mesorectal excision, transanal ileorectal bypass, and transvaginal appendectomy with good results and without complications (17).

Thiel's cadavers are suitable for surgical training of microvascular anastomotic techniques (18). When the vessels are infused with additional colored latex they become firm and even small arteries are apparent; but the cadavers are then inappropriate for procedures where uninterrupted vasculature is needed (9). However, those cadavers are useful for studying vascular variations (19).

Figure 1. *Arteries injected with mixture of latex and red dye.*

The cadavers are suitable for different imaging techniques such as MRI, where distinguishing between white and grey matter of the brain is seen; as well as for ultrasound, where images are of equivalent quality as those acquired from living individuals (3).

One new technique that is being developed is MRI–guided focused ultrasound surgery (MRgFUS), where Thiel emblamed cadavers serve as an ideal model. The cadavers are anatomically correct, can be ventilated to simulate diaphragmatic motion, and the circulation can be simulated; they are appropriate for MRI and the tissue even warms up in response to MRgFUS (14). Thiel embalmed cadavers are a suitable model for ultrasound–guided regional anestesia (USGRA) of the cervical region because the structures are visible and result in easier puncture compared to fresh cadavers. A realistic sensation is transmitted when passing the fascia during puncture (8).

Current urological training is being undertaken on Thiel embalmed cadavers, particulary laparoscopy, retrograde pyeloureterography, upper and lower urinary tract endoscopy, and renal angiography (13). Thiel's embalming method is also an appropriate milieu for simulated renal transplant surgery (4).

The cadavers serve as models for the development and evaluation of medical devices and procedures, including new USGRA techniques and equipment, laparoscopic devices, laryngoscopes, retractors, and hip and shoulder prostheses (7).

Table 3. Ingredients for immersion solution.

Immersion solution 1998	
Hot tap water	91
Boric acid	3
Monopropylen glycol	10
Ammonium nitrate	10
Potassium nitrate	5
Ethanol	9
Formaldehyde	2
Sodium sulfite	7
Basic solution II 1998	2

Units for liquid chemicals are given in mililiters, and for solid chemicals in grams. 1 mL=1 g.

METHODS

In the first step, intravascular perfusion of the solution (Table 2) is applied (14). The original method describes applications through the superior sagittal sinus and external iliac artery, but was modified by application through the carotid and femoral arteries (1, 3). At the end of perfusion, other dyes, resins, latex, and lead tetraoxide are added to ensure the identification of the thinnest vascular branches, as well as the entire vascular system can be injected (Figure 1). The injected mass also provides high radiopacity and offers an ideal firmness for dissection (3, 20). After perfusion, the cadaver looks inflated (7). Bodies are then immersed in basin of solution (Table 3) for at least 4–6 months (14). After this period, cadavers can be left submerged in the basin or kept in plastic bags without any need for refrigeration, and can be used for months or years (3, 7). During storage in the plastic bags, most of the injected fluid is drained out and the body returns to its previous shape and size. If the cadaver is dried out it can be put back into the basin to recover color and flexibility (7).

Figure 2. *The preservation of the natural color and texture.*

RESULTS

Figure 3. *Basins for the storage of cadavers in immersion solution.*

When the Faculty of Medicine in Maribor was established, the decision to use Thiel's embalming method was made and the adapation of the institute's building granted for its requirements. The faculty also established its own body donation program. Potential donors sign a written consent to donate their remains for educational and scientific purposes, and receive a card where all data and instructions are written in case of death. The first cadaver was embalmed in 2008; a total of 16 bodies were embalmed until 2013, including 9 men and 7 women.

One of the most difficult tasks was to develop a special device that displaces chemicals with the help of carbon dioxide, and applies them into the body under a pressure equal to that of living humans (Figure 4). In the begining, we started perfusions via the superior sagittal sinus and femoral artery and later changed to the carotid and femoral arteries. Technical difficulties in perfusion of the femoral artery can occur due to atherosclerosis (1). We do not use additional mixtures containing dyes and resins. The body then remains outside the basin until the next day, when the brain is removed because of better fixation in 10% formalin. After perfusion, the cadavers are stored in immersion solution in the basins (Figure 3) for approximately 6 months, and are then placed in zipper polyethylene bags at 4° C in the refrigerator for months to years. To prevent drying out, particulary if stored in the refrigerator, the cadavers are moistened with glycerol solution. The cadavers that are used for a longer period of time, such as during an anatomy course, are kept in the dissecting room at temperature between 16° C and 18° C. Cadavers that are not needed stay in the basins.

We primarily use cadavers for anatomy education, prosections, and dissections, and are in favor of Thiel embalmed cadavers. The cadavers are of natural color, texture, and flexibility, very similar to that of living individuals and with characteristics close to fresh cadavers, compared with formalin embalming (Figure 2). The tissue characteristics that are acquired during Thiel's embalming method are a result of three processes: fixation, disinfection, and preservation with chemicals. Arteries and veins remain permeable: the skin, muscles, fascia, and peritoneum are flexible such as in living humans. The cadavers are of high anatomic accuracy, simulating exact anatomical planes and three–dimensional (3D) anatomical structures, as well as spatial and topographical relationships. These are the most important features that students learn only from cadaveric education, with the exception of living humans during clinical practice.

The most negative impact for students is psychological, because of their realistic appearance. To overcome this uncomfortable situation, students are mentally prepared prior to the first handling. In the first few practical sessions, the head is covered with a sheet so the discomfort is minimized. When the cadavers are no longer suitable for use, they are cremated and their ashes placed at Dobrava cemetary with a memorial board.

There have been a few individual attempts of arthroscopy and intubations at our institute on Thiel embalmed cadavers (not published). Thiel embalmed cadavers have been evaluated as a new training model for urethrocystoscopy and ureteroscopy (21). Our future plans are to test the anchoring system in the surgical treatment of disorders of pelvic floor function on Thiel embalmed cadavers.

Figure 4. *Special devise for intravascular perfusion.*

DISCUSSION

Seventy–eight percent of European anatomists are familiar with the Thiel method, particulary in German–speaking countries, although only 11 centers (Graz, Austria and Dijon, France excluded) use this technique in routine practice. Obstacles to the use of this method lies in the fact that the original article was in German, as well as the high costs compared with alternative techniques (11). One of the main advantages for us to use this technique was our proximity to Graz, where our staff were educated. Most of the people from our region speak German, in addition to the fact that the Thiel embalming method is one of the best researched methods of cadaveric preservation (22). The high costs are justified by the fact that cadavers can be used for several years and for generations of medical students. From the time we began using our own cadavers for teaching purposes, more then 90 students per year have learned anatomy on only 16 cadavers. The oldest cadaver that is still used for teaching purposes was embalmed in 2009. In addition, the same cadavers that have been used for educational purposes have also been used for minor research studies. We can therefore confirm in the literature that a large number of varied procedures can be performed on the same cadaver (14).

In the beginning, we had many technical problems that were resolved or even improved through practice, especially because of the amount of chemicals that have to be mixed together do not disolve quickly despite of the usage of hot water; most of them are salts (1).

When the cadavers are maintained in plastic bags in the refrigerator, they dry quickly and have to be moistened according to the original method with a special mixture of immersion fluid. However, our experience shows that they remain moist even if glycerol

solution is used (1). Our results of preservation after the removal from the basin exceed those obtained by Healy et al., who reported preservation for more than a year, and Bertone et al., for 3 years; one of our cadavers has been in the refrigerator for 6 years with no major changes in features except for distal mumification and desquamation (also found by Eisma et al. (7, 13, 23). The long preservation period could be due to use of glycerol solution, that provides moisture, and dissecting room temperatures during the educational process. When cadavers are not needed for this purpose, they are stored in the refrigerator, as reported by Kerckaert et al. (2).

Since the faculty has moved to a new location with modern, up–to–date technology for education and research, the anatomy lab has been equipped with a virtual 3D atlas and virtual dissection tables. In anatomy education, the main advantage of cadavers, or the "silent teacher," represents knowledge that cannot be found in textbooks or obtained from models or 3D software programs (14). No technology can substitute for the first contact of the student with a cadaver, the sensing of different types of tissue, the exploration in the course of dissection, and at the same time learning from the body. This also involves individual anatomic variations, the impact of disease and lifestyle on the body, and tissue diversity (14). Cadavers must stay in the curriculum for future clinical practice of students; many residents and specialists want to practice and learn on bodies. To clarify why anatomic knowledge is necessary later in the clinic, the Endogent Centre for Anatomy and Invasive Techniques at Ghent University intends to demonstrate surgical approaches to their undergraduate medical students at the begining of the medical curriculum on Thiel embalmed cadavers, in addition to dissections and prosections. Collaboration between anatomists and clinicians is required for the future development of both (2).

CONCLUSIONS

The Thiel embalming technique provides all the features necessary for effective preservation of cadavers, since it ensures more realistic conditions, long–lasting preservation, and reduced cost. This method has been successfully applied in our education curriculum and research field.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

REFERENCES

1. Thiel W (1992) Die Konservierung ganzer Leichen in natürlichen Farben. Ann Anat 174:185–95.
2. Kerckaert I, Van Hoof T, Pattyn P, D'Herde K (2008) Endogent: Centre for anatomy and invasive techniques. Anatomy 2: 28–33.
3. Ottone NE, Vargas CA, Fuentes R, del Sol M (2016) Walter's Thiel embalming method. Review of solutions and applications in different fields of biomedical research. Int J Morphol 34:1442–54.
4. Cabello R, González C, Quicos C, Bueno G, García JV, Arribas AB et al. (2014) An experimental model for training in renal transplantation surgery with human cadavers preserved using W. Thiel's embalming technique. J Surg Educ 72:192–7.
5. Thiel W (1992) Die Arterienmasse zur Nachinjektion bei der Konservierung ganzer Leichen. Ann Anat 174:197–200.
6. Hayashi S, Naito M, Kawata S, Qu N, Hatayama N, Hirai S et al. (2016) History and future of human preservation for surgical training: from formalin to saturated salt solution method. Anat Sci Int 91:1–7.
7. Eisma R, Lamb C, Soames RW (2013) From formalin to Thiel embalming: What changes? One

anatomy department's experiences. Clin Anat 26:564–71.
8. Benkhadra M, Faust A, Ladoire S, Trost O, Trouilloud P. Girard C et al. (2009) Comparison of fresh and Thiel's embalmed cadavers according to the siutability for ultrasound-guided regional anesthesia of the cervical region. Surg Radiol Anat 31:531–5.
9. Eisma R, Mahendran S, Majumdar S, Smith D, Soames RW (2011) A comparison of Thiel and formalin embalmed cadavers for thyroid surgery training. Surgeon 9:142–6.
10. Balta JY. Cronin M, Cryan JF, O'Mahony SM (2015) Human preservation techniques in anatomy: A 21st century medical education perspective. Clin Anat 28:725–34.
11. Benkhadra M, Gérard J, Genelot D, Trouilloud P, Girard C, Anderhuber F et al. (2011) Is Thiel's embalming method widely known? A world survey about its use. Surg Radiol Anat 33:359–63.
12. Feigl G, Kos I, Anderhuber F, Guyot JP, Fasel J (2008) Development of surgical skill with singular neurectomy using human cadaveric temporal bones. Ann Anat 190:316–23.
13. Heally SE, Rai BP, Biyani CS, Eisma R, Soames RW, Nabi G (2015) Thiel embalming method for cadaver preservation: A review of new training model for urologic skills training. Urology 85:499–504.
14. Eisma R, Wilkinson T (2014) From "silent teachers" to models. PLoS Biol 12:e1001971.
15. Feigl G, Benkhadra M, Lenfant F, Trouilloud P, Anderhuber F, Bonniaud P et al. (2008) Bronchoscopy and cricothyrotomy: results from cadavers embalmed with Thiel's method compared to other embalming methods and living subjects. Acta Medico-Biotechnica 1:25–36.
16. Giger U, Frésard I, Häfliger A, Bergmann M, Krähenbühl L (2008) Laparoscopic training on Thiel human cadavers: A model to teach advanced laparoscopic procedures. Surg Endosc 22:901–6.
17. Porzionato A, Polese L, Lezoche E, Macchi V, Lezoche G, Da Dalt G et al. (2015) On the suitability of Thiel cadavers for natural orifice transluminal endoscopic surgery (NOTES): surgical training, feasibility studies, and anatomical education. Surg Endosc 29:737–46.
18. Hassan S, Eisma R, Harry LE (2014) Surgical training of anastomotic technique using Thiel cadavers. J Plast ReconstrAesthet Surg 67:e250–1.
19. Kocbek L, Krajnc I, Anderhuber F (2011) Anatomical variations of the posterior intercostal arteries and the thoracic vertebral artery. J Int Med Res 39: 1001–5.
20. Thiel W (2002) Ergänzung für dir Konservierung ganzer Leichen nach W. Thiel. Ann Anat 184:267–9.
21. Bele U, Kelc R (2016) Upper and lower urinary tract endoscopy training on Thiel-embalmed cadavers. Urology 93:27–32.
22. Brenner E (2014) Human body preservation – old and new techniques. J Anat 224:316–44.
23. Bertone VH, Blasi E, Ottone NE, Dominguez ML (2011) Walther Thiel method for the preservation of corpses with maintenance of the main physical properties of vivo. Rev Argent Anat Online 2:89–92.