CADAVERIC EMBALMING USING A MODIFIED THIEL METHOD AS AN ALTERNATIVE TO THE FORMALIN METHOD

Caswell Hachabizwa[1], Mickey Banda[1] Joseph Hainza[1], Sikhanyiso Mutemwa[1], Krikor Erzingastian[2], Elliot Kafumukache[2]

[1]Department of Anatomy, School of Medicine, University of Zambia, Lusaka, Zambia

[2]Department of Surgery and Anatomy, School of Medicine, University of Zambia, Lusaka, Zambia

Correspondence to Dr. Caswell Hachabizwa. Email: caswellhachabizwa@gmail.com

ABSTRACT

Formalin embalming method is cheaper and commonly used. Thiel method is said to be complex, expensive, not commonly used but offers better cadavers for student teaching. The study aimed at exploring the effects of two embalming methods; modified Thiel and formalin methods on cadavers in terms of muscle softness, joint flexibility, tissue colour, formalin smell and the ease with which structures can be identified. This was an experimental study design done over the period of three months where four adult male cadavers were embalmed (two under each method) and the outcome was compared. Using gravity about Ten Litres of arterial and five Litres venous Thiel fluids was slowly infused into each Thiel cadaver through the carotid artery and femoral vein respectively and cadavers remained overnight. Thiel cadavers were submerged in the tank containing about 300L of Thiel fluid, covered with a blanket and left for eight weeks. Each formalin cadaver was infused with about 15Litres of 10% formalin using the carotid artery and then wrapped in transparent plastics. Thereafter, cadavers were codified and placed in different rooms where participants examined and dissected some regions starting with Thiel cadavers and crossing over to the formalin cadavers after twenty-four hours. Thiel cadavers were softer than formalin (mean = 4.89 ± 0.53 Thiel and 2.1 ± 1.26 for formalin). For joint flexibility, at least 75% of participants strongly agreed for Thiel and at least 75% of the participants strongly disagreed for formalin (mean = 4.81 ± 0.86 Thiel and 1.71 ± 1.13 formalin). Tissue colour was closer to natural in Thiel compared to the formalin cadavers (mean = 4.82 ± 0.55 Thiel and 1.77 ± 1.07 formalin). There were no complaints due to irritant formalin smell in Thiel cadavers as opposed to the formalin ones (mean = 1.15 ± 0.55 Thiel and 4.56 ± 1.15 formalin). At least 75% agreed that it was easy to identify structures in the Thiel cadavers than formalin (mean = 4.67 ± 0.61 and 2.61 ± 1.14 formalin). Thiel embalming method offers good quality cadavers that are soft, flexible; tissue colour closer to natural state and without is strong formalin smell and structures can easily be identified.

Key words: *Cadaveric embalming, modified Thiel, formalin methods*

INTRODUCTION

The human bodies are used as distinct educational tools in teaching gross human anatomy (Brenner 2003). The quality of preservation of human remains has enabled such use (Balta 2015, Anastakis 1999). Good embalming technique is one that makes the cadaver stay long without decomposing, free from infectious organisms, pliable and to some extent conserves tissues as close as possible to the living state (Thiel, 1992; Coleman, 1998; Benkhadra, 2011a). In his study, Hayashi (2014) mentioned and compared four embalming techniques namely; fresh-frozen cadaver, formalin based, Thiel's embalming technique and saturated salt solution methods. Of the four techniques, formalin (formaldehyde) based is the most commonly practiced, due to its low cost and wide availability. However, it is not ideal because formaldehyde has an adverse health effects (Brenner 2014;

Binawara *et al.*, 2010; Chia *et al.,* 1992), some of which are unpleasant smell and mucosal irritation (Okan *et al.,* 2017). In 1992, the new cadaveric preservation method was introduced by Professor Dr. Walter Thiel by using the combination of both organic and inorganic compounds known as "Thiel's solution" (Sangchay, 2014). The Thiel embalming method results in soft and flexible cadavers with almost natural colours and such cadavers have been appraised widely (Thiel, 1992; Suniti *et al.*, 2016; Bele *et al.,* 2016; Yiasemidou *et al.,* 2017). However, Thiel's method is relatively complex and expensive (Benkhadra 2011a, Eisma 2013). Hence, a number of modified Thiel techniques have been adopted in many set ups to suit the requirements (Hammer, 2012; Brenner 2014; Ottone, 2016)

In the School of Medicine at the University of Zambia, Formalin based embalming method is the one used to embalm cadavers used for student dissection. Therefore, this research was focused on the Thiel embalming method as a tool to enhance the teaching of anatomy to both undergraduate and postgraduate students in the School of Medicine department of Anatomy in Zambia.

METHODOLOGY

Two embalming methods were used (two cadavers under formalin and two under Thiel). Cadavers were cleaned and disinfected and then cannulated in carotid artery and femoral vein for the Thiel method. Vascular Perfusion was gravity dependent with chemical containers placed four meters high. The standard formalin Solution comprises 30L of 10% formalin; 2.5L ethanol; 0.5L glycerin and 250g phenol. 15 L formalin was infused into two cadavers and cadavers were then wrapped into plastics in readiness for use after 21 days.

Thiel solution used was as indicated in the table 1 below. The table below shows quantities of the Thiel solution that was used in the study to embalm two Thiel cadavers. Stock II shown in the table below is a mixture of 1 kg chlorocresol (4-chloro-3-methy phenol) in 10 L of glycol. About 10L arterial Thiel solution and 5L venous Thiel solutions were slowly infused into each of the two cadavers

overnight. After 12 hours Thiel cadavers were submerged in the tank containing 280L Thiel fluid for eight weeks after which, were removed, covered in plastics and taken to the dissection room.

Cadavers were then coded and placed in two different rooms. Seventy-six third year medical students and three Anatomy postgraduate students examined and dissected some regions on the cadavers and completed questionnaires. Students were blinded on each cadaver group. They started with the Thiel cadavers and then crossed over to the formalin cadavers after twenty-four hours. The five-point Likert scale was used to collect the data. Data was analyzed by descriptive statistics using STATA software version 13. The data was analyzed using the mean and standard deviations. Frequency tables, figures and bar charts were used for presentation of data

Table 1: Composition of Thiel Embalming Fluids used in the study based at the University Zambia Anatomy Department.

Additives	Arterial infusion	Venous infusion	TANK FLUID	MOISTENING
Hot tap water	6.8 L	1.45 L	208 L	20 L
Boric acid	250 g	80 g	7.5 KG	600 g
Ammonium nitrate	1680 g	520 g	25 KG	–
Potassium nitrate	420 g	130 g	12.5 KG	–

Sodium sulphite	700 g	190 g	17.5 KG	1 kg
Propylene glycol	2.5 L	780 ml	25 L	1 L
Stock II	500 ml	190 ml	5L	200 mL
Formaldehyde solution (10 %)	2.1 L	1.5 L	21 L	–
Alcohol	1 L	1.1 L		–
Total volume [L] ca.	13	5.5	259~286	22

Eisma 2013

Figure 1: Perfusion of the Thiel fluid through the carotid artery and the femoral vein

Figure 2: Thiel tank containing Thiel cadavers

RESULTS

Data collected using the 5-point Likert scale from 79 participants showed that Thiel cadavers were better than the formalin cadavers in terms of *muscle softness, joint flexibility, tissue colour,* absence of *irritant formalin smell* and the *ease with which structures could be identified* compared to the formalin.

Table 2 shows that at least 75% of the study participants strongly agreed that their muscles were soft (Q1 = 5, median = 5, Q3 = 5 and max = 5), with the mean lying between agreed

and strongly agreed (mean = 4.89) as a result of the pulling effect of a few outliers (min = 1). The picture was the same for the flexibility of cadaver joints to which at least 75% of the participants strongly agreed (mean = 4.81, min = 1, Q1 = 5, median = 5, Q3 = 5, max = 5), and the tissue colour being closer to the natural state to which at least 75% strongly agreed (mean = 4.82, min = 1, Q1 = 5, median = 5, Q3 = 5, max = 5). To the question whether there were complaints due to strong formalin smell, at least 75% strongly disagreed (min = 1, Q1 = 1, median = 1, Q3 = 1), with a few

Table 2: Summary statistics for the Thiel embalming method

Variable	n	Mean	S.D.	Quantiles				
				Min	0.25 (Q1)	Median	0.75 (Q3)	Max
Muscle softness	79	4.89	0.53	1	5	5	5	5
Joints flexibility	79	4.81	0.56	1	5	5	5	5
Tissue color	79	4.82	0.55	1	5	5	5	5
Complaints due to formalin smell	79	1.15	0.66	1	1	1	1	5

Ease of identification of structures	79	4.67	0.61	3	4	5	5	5

outliers (max = 5) having a pulling effect on the mean (mean = 1.15), making it lie between disagreed and strongly disagreed. On the ease of identification of structures, at least 50% strongly agreed and 25% agreed, putting those who at least agreed at 75%. 25% of the participants were at least neutral. The Shapiro-Wilk tests were conducted to ascertain the normality of the distributions of the data. From the test results shown in table 3, we rejected the null hypothesis and concluded that the data distributions were not normal for the Thiel method in all the cases (p < 0.05).

For the Formalin embalming method, the summary statistics from table 4 show that at least 50% of the participants disagreed with the assertion that the cadaver muscles were soft (median = 2). Out of these, at least half strongly disagreed (Q1 = 1). The middle 50% of the participants' responses fell between strongly disagree and neutral (Q3 = 3) while 25% either agreed or strongly agreed (max = 5). On average, the participants disagreed with the assertion (mean = 2.1). At least 75% of the participants disagreed with the assertion that the cadaver joints were flexible, with 50% strongly disagreeing. This pattern is the same on the issue of tissue colours being closer to natural state (median = 1, Q3 = 2). At least 75% strongly agreed to the assertion that there complaints due to formalin smell (Q1 = 5). On the ease of identification of structures, most participants' responses fell between disagree and neutral (mean = 2.61, Q1 = 2, median = 3, Q3 = 3).

Table 3: Shapiro-Wilk test of normality results for the Thiel embalming method

Variable	n	W	V	z	p - value
Muscle softness	79	0.17882	55.787	8.805	0.00
Flexible Joints	79	0.4267	38.947	8.019	0.00
Tissue color	79	0.40145	40.662	8.113	0.00
Complaints due to formalin smell	79	0.57885	28.611	7.343	0.00
Ease of identification of structures	79	0.85845	9.616	4.956	0.00

Table 4: Summary statistics for the Formalin embalming method

Variable	n	Mean	S.D.	Quantiles				
				Min	0.25 (Q1)	Median	0.75 (Q3)	Max
Muscle softness	79	2.1	1.26	1	1	2	3	5
Flexible Joints	79	1.71	1.13	1	1	1	2	5
Tissue color	79	1.77	1.07	1	1	1	2	5
Complaints due to formalin smell	79	4.56	1.15	1	5	5	5	5
Ease of identification of structures	79	2.61	1.14	1	2	3	3	5

Table 5: Shapiro-Wilk test of normality results for the Formalin embalming method

Variable	n	W	V	z	p - value
Muscle softness	79	0.92916	4.813	3.44	0.00
Flexible Joints	79	0.85418	9.906	5.021	0.00
Tissue colour	79	0.86947	8.868	4.779	0.00
Complaints due to formalin smell	79	0.71025	19.684	6.524	0.00
Ease of identification of structures	79	0.98577	0.966	-0.075	0.53

For the formalin embalming method data, the Shapiro-Wilk tests were likewise conducted to ascertain the normality of the distributions. From the test results shown in table 5, we rejected the null hypothesis and concluded that the data distributions were not normal for muscle softness ($p < 0.05$), flexibility of joints ($p < 0.05$), tissue colour ($p < 0.05$) and complaints due to formalin smell ($p < 0.05$). In the case of the ease of identification of structures, we failed to reject the null hypothesis and concluded that there was no sufficient evidence for us to prove that the data was not normally distributed ($p > 0.05$).

Tests of difference between the two methods

In order to test whether the observed differences between the two embalming methods were statistically significant, the Mann Whitney U test of difference was conducted. The non-parametric test was chosen because the data was not normally distributed as shown by the test results in table 6.

The results from table 6 above show statistically significant differences between the median ranks of the two embalming methods in all the five aspects. We therefore rejected the null hypothesis and concluded that there is a difference between the Thiel and Formalin embalming methods with regards to cadaver muscle softness ($U = 364$, $p < 0.05$, 2-tailed), flexibility of joints ($U = 281$, $p < 0.05$, 2-tailed), tissue color ($U = 214$, $p < 0.05$, 2-tailed), complaints due to formalin smell ($U = 301$, $p < 0.05$, 2-tailed) and the ease of identification of structures ($U = 479$, $p < 0.05$, 2-tailed).

Table 6: Wilcoxon ranksum (Mann Whitney U) test results

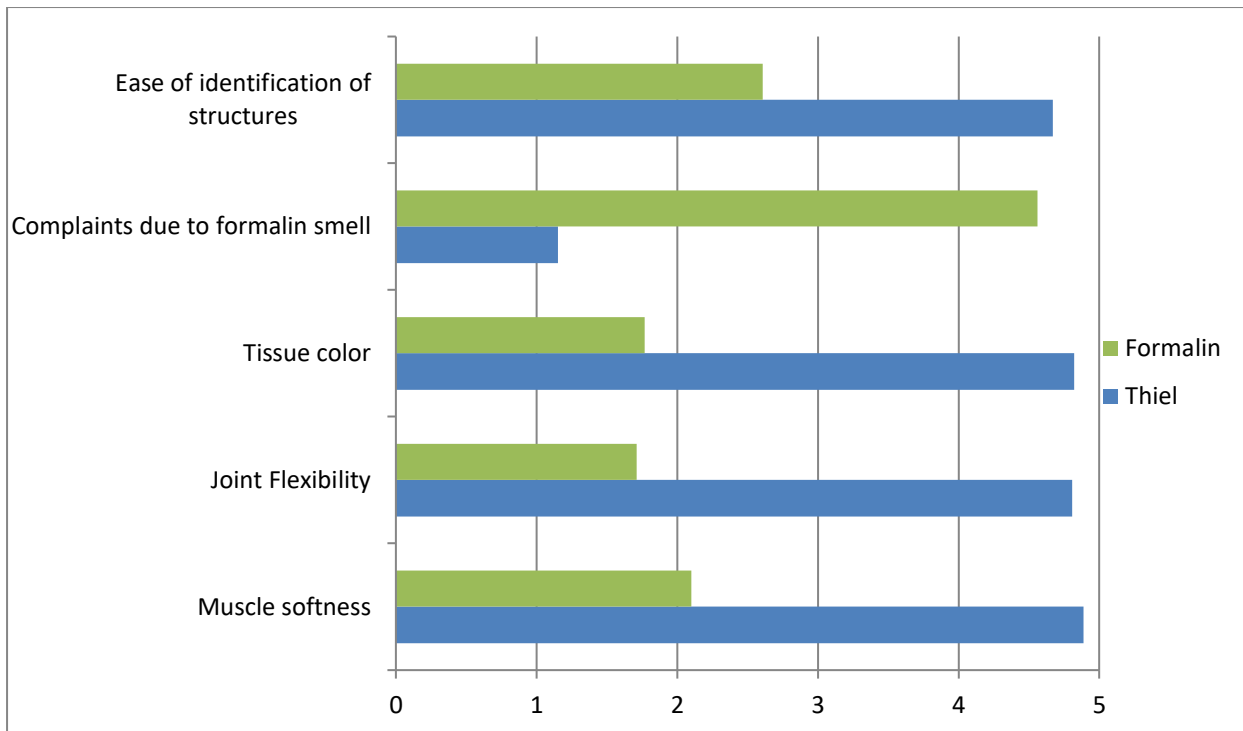| Variable	N	z	U	p - value
Muscle softness	79	10.382	364.000	0.000
Flexible Joints	79	10.537	281.500	0.000
Tissue color	79	10.742	214.500	0.000
Complaints due to formalin smell	79	-10.996	301.000	0.000
Ease of identification of structures	79	9.557	79.000	0.000

Figure 3: Bar chart showing mean responses for the formalin and Thiel methods. Fig 3. Bar chart shows the mean response results that were collected from questionnaires from 79 participants of third year medical students and postgraduate master's degree students who participated in cadaver assessment and dissections. (**Note:** in 4 categories including, *identification of structures, tissue colour, joint flexibility & muscles softness,* the score of 5 means strongly agreeing (similar to live human). In *formalin smell* category, the score of 5 means presence of strong formalin smell).
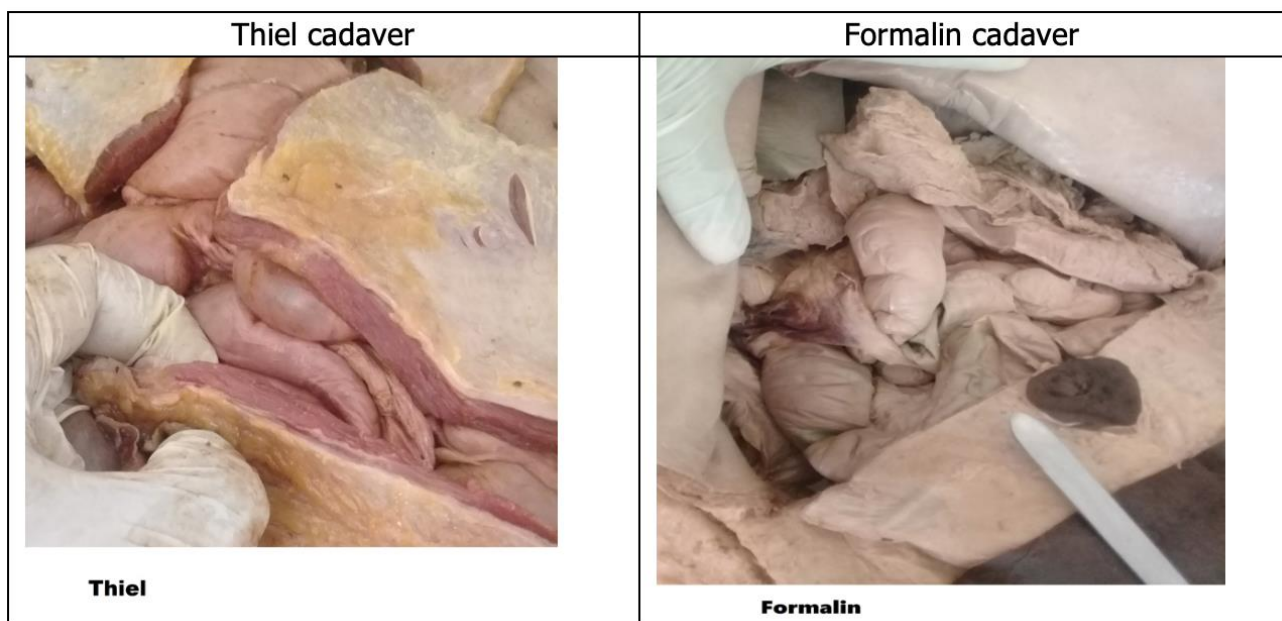
Figure 4: Tissue colour for Thiel and formalin cadavers

DISCUSSION

This chapter discusses the results of the study on the two embalming methods (Thiel and formalin) in Zambian. The study evaluated student opinion on the outcome of the two embalming methods, modified Thiel method and the formalin method.

The results suggest that modified Thiel cadavers may be suitable for student dissection than the formalin method. Thiel cadavers were found to have soft muscles, flexible joints, and tissue colour closer to natural state. Thiel cadavers had no strong formalin smell and it was easy for students to identify structures. Contrary to this, in formalin cadavers muscles were not soft, joints were stiff with tissue colour that does not resemble the natural state. The cadavers also had strong formalin smell while participants had difficulties in identifying structures in these cadavers. The results of this study are in line with previous comparative studies by, Eisma *et al*, 2011; Holzle *et al,* 2012; Giger *et al,* 2008; Wolff *et al.,* 2008; Thiel, 1992 which found Thiel cadavers to be ideally suited for student dissections.

On palpation and close examination of the cadavers, Thiel cadavers were observed to have *softer* muscles compared to those embalmed using the formalin method. These results are consistent with what was reported by Brenner 2014; Suniti *et al.*, 2016. This muscle softness quality is imparted by the propylene glycol and various salts which are components of the Thiel fluids. *Joint flexibility* was excellent in Thiel cadavers as opposed in formalin ones. The range of joint movement was maintained just like in the living body. 67 out of 79 participants strongly agreed and 11 agreed to the assertion that joints were flexible in the Thiel cadavers. At least 76 out of 79 participants disagreed that joints were flexible in the formalin cadavers. These results match with what was reported in studies done by Thiel 1992; Eisma *et al.*, 2011; Sangchay 2014. Generally the two Thiel cadavers exhibited the similar qualities in terms of joint flexibility except minor variation in the movement of the metacarpophalangeal and interphalangeal joints. Such variation could be due to the use of unclaimed cadavers that overstayed before being embalmed. The cadavers showed desiccated extremities even before the embalming process was done leading to distortion of the results.

Thiel cadavers retained natural tissue *colours* just like in the living state. 68 out of 79 participants strongly agreed while 10 agreed that tissue colour was closer to natural state in the Thiel cadavers compared to the formalin embalmed cadavers. While there was brownish coloration of tissues in the Formalin cadavers the tissue colours in Thiel cadavers were maintained closer to natural state in the formalin cadavers. These findings are similar to studies done by Thiel 1992; Suniti et al., 2016, Bele *et al.*, 2016.

Concerning *formalin smell* emitted by cadavers during dissection, the results from the 5 point Likert scale showed that there was no complaint associated with formalin smell in the Thiel cadavers. 93% of the respondents stated that there was no formalin smell in the Thiel cadavers while 83.58% of respondents agreed that there was strong formalin smell in the formalin cadavers. These results are in line with other comparative studies done by Brenner 2014; Eisma *et al.,* 2014 and Okan 2017. Absence of formalin smell is based on the principle that the modified Thiel embalming method uses a very small amount of formalin. This factor was also mentioned by Eisma *et al.,* 2013; in his study where he stated that percentage of formalin is very low in the Thiel embalming method. This study agrees to the fact that the amount of formalin is less keeping in mind the use of 21L of 10% formalin in 280L of fluid containing other chemicals in the tank.

In terms of *structural identification*; at least 73 out of 79 respondents agreed that it was easier to identify structures in the Thiel cadavers compared to the formalin cadavers. Good tissue texture, preservation of natural colours, cadaver flexibility and absence of irritant formalin smell made it easy for respondents to identify some structures in the Thiel cadavers compared to the formalin cadavers. This is in line with findings by Eisma *et al,.* 2014 who

reported Thiel cadavers being flexible and easy to manipulate in an effort to identify structures.

Results from the software analysis (STATA version 13) using the Wilcoxon rank sum (Mann Whitney U) test showed the calculated p-value < 0.05 indicating significant difference between the two embalming methods. These results are similar to the findings in the study done by Kennel *et al.,* (2018) who investigated and compared students' attitudes towards the dissection experience with Thiel and formalin embalmed cadavers.

We calculated the cost of embalming two Thiel cadavers to be K45000 ($3419.45) while K3000 ($277.96) was spent on 2 formalin cadavers. We therefore stimated the cost of embalming one Thiel cadaver to be fifteen times more than the cost of embalming one formalin cadaver. This estimate is higher than that of Benkhandra *et al.,* (2011) which set Thiel embalming method to be ten times more expensive than the fomalin method. This variation could be attributed to the fact that the thiel method is being done for the first time in our set up and all additional equipment had to be procured thereby raising the cost.

We deviated from Thiel's original method of the embalming process by not infusing the Thiel solution into the cavities (cranial, thoracic and abdominal) and the cadavers were submerged in the tank for only two months instead of six months (Thiel 1992). Our chemical composition was closer to that used by Eisma *et al.,* 2014 even though we used 10% formalin instead of 8.9%. We did not include the chemical substance Morpholine as it was not available at that time. Just like other modified Thiel methods done elsewhere, we got impressive results but we did not attempt to compare our results to those of similar studies done elsewhere. This trend is consistent and was reported by Ottone *et al.,* (2016) who mentioned that despite variations in the applications of the Thiel embalming method, all studies have yielded similar results.

Limitation of the study

There were poor facilities to carry out the study as most equipment had to be procured specifically for this research. This made the whole study more expensive. Equally unclaimed bodies were used in the study. Such bodies stayed for long period of time before the process of embalming was done.

Conclusion

Embalming cadavers using a modified Thiel method offers excellent cadavers in terms of muscle softness, joint flexibility and tissue colour closer to natural state. Such cadavers have minimal complaints associated to formalin smell while structures can easily be identified. Thiel cadavers can therefore offer a better tool in teaching human gross anatomy to medical students as opposed to the use of formalin method.

REFERENCES

1. Anastakis DJ, Regehr G, Reznick RK.1999. Assessment of technical skills transfer from the bench training model to the human model. Am J Surg. 177:167.
2. Balta JY, Cronin M, Cryan JF, O'Mahony SM. 2015a. Human preservation techniques in anatomy: a 21st century medical education perspective. Clin Anat. 28:725–734.
3. Balta JY, Lamb C, Soames RW. 2015b. A pilot study comparing the use of Thiel- and formalin-embalmed cadavers in the teaching of human anatomy. AnatSciEduc 8:86–91
4. Bele U and Kelc R. 2016. Upper and Lower Urinary Tract Endoscopy Training on Thiel-embalmed Cadavers.93:27-32.
5. Benkhadra M, Bouchot A, Gerard J et al. 2011b. Flexibility of Thiel's embalmed cadavers: the explanation is probably in the muscles. SurgRadiolAnat 33:365–368.
6. Benkhadra M, Gerard J, Genelot D et al. 2011a. Is Thiel's embalming method widely known? A world survey about its use.SurgRadiolAnat 33:359–363.
7. Okan Bilge O and Celic S. 2014. Cadaver embalming fluid for surgical training courses: modified Larssen solution,J Anat.224(3): 316–344.
8. Binawara BK, Rajnee CS, Mathur K, Sharma H, Goyal K. 2010. Acute effect of formalin on pulmonary function tests in medical students. Pak J Physiol 6:8–10.
9. Brenner E .2014. Human body preservation – old and new techniques. Journal of Anatomy 224(3): 316–344.
10. Chia SE, Ong CN, Foo SC, Lee HP. 1992.Medical students' exposure to formaldehyde in a gross anatomy dissection laboratory. J Am Coll Health 41:115–119.
11. Coleman R, Kogan I. 1998.An improved low-formaldehyde embalming fluid to preserve cadavers for anatomy teaching.JAnat 192:443–446.
12. Eisma R, Lamb C, Soames RW .2013. From formalin to Thiel embalming: what changes? One anatomy department's experiences.ClinAnat 26:564–571.
13. Eisma R, Mahendran S, Majumdar S, Smith D, Soames RW. 2011. A comparison of Thiel and formalin embalmed cadavers for thyroid surgery training. Surgeon 9:142–146.
14. Eisma R, Wilkinson T. 2014.From "silent teachers" to models.PLoSBiol 12:e1001971 retrieval date 15.03.2018
15. Giger U, Fresard I, Hafliger A, Bergmann M, Krahenbuhl L. 2008. Laparoscopic training on Thiel human cadavers: a model to teach advanced laparoscopic procedures. SurgEndosc 22:901–906.
16. Hayashi S, Homma H, Oda J, Nishiyama T et al. 2014. Saturated Salt Solution Method: A Useful Cadaver Embalming for Surgical Skills Training Medicine. 93(27):196
17. Hayashi S, Naito M, Kawata S, Qu N, Hatayama N, Hirai S, Itoh M. 2016.
18. History and future of human cadaver preservation for surgical training: from formalin to saturated salt solution method.AnatSciInt.91(1):1-7.
19. Hölzle F, Franz EP, Lehmbrock J (2012). Thiel embalming technique: a valuable method for teaching oral surgery and implantology. Clin Implant Dent Relat Res, 14(1): 121-6.
20. Ottone, N. E.; Vargas, C. A.; Fuentes, R. & Del Sol, M.2016.Walter Thiel's embalming method. Review of solutions and applications in different fields of biomedical research. Int. J.Morphol. 34(4):1442-1454.

21. Sangchay N. 2014. The Soft Cadaver (Thiel's Method): The New Type of Cadaver of Department of Anatomy, Siriraj Hospital. Siriraj Med J 2014;66(Suppl):S228-S231. Retrieval date 21.03.2018.

22. Suniti RM , Jigyasa P, Rahul S, Raveena S, Sushobhana, Priyanka S.2016. Embalming fluid - modified composition for hot and humid places.Int J Anat Res. 4(3):2531-2535.

23. Thiel W. 1992. The preservation of the whole corps with natural colour. Ann Anat 174:185–195.

24. Wolff KD, Kesting M, Mücke T, Rau A, Hölzle F .2008. Thiel embalming technique: a valuable method for microvascular exercise and teaching of flap raising. Microsurgery. 28(4):273-8.