ORIGINAL COMMUNICATION

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

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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 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;
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    | –          |
### 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 5 |
| Joints flexibility              | 79 | 4.81 | 0.56 | 1 5 5 5 5 5 |
| Tissue color                    | 79 | 4.82 | 0.55 | 1 5 5 5 5 5 |
| Complaints due to formalin smell| 79 | 1.15 | 0.66 | 1 1 1 1 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 | -    | 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. The cadaver's 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 estimated 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 formalin 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.

ACKNOWLEDGEMENTS: My sincere thanks go to my supervisor Doctor E. Kafumukache and Co-supervisor Professor K. Erzingatsia for the stepwise guidance that helped me to complete my study project. I equally thanks my colleagues, family and friends for their encouragement and support. My utmost appreciation goes to my sponsors: The Lusaka Apex Medical University (LAMU) for the financial support making it possible for me to pursue Masters of Science in Human Anatomy and complete my research project.
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