

## Original Article

# Soft embalming of cadavers for training purposes: Optimising for long-term use in tropical weather

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### ABSTRACT

**Background:** Surgical and anatomical training has been found to be most optimally simulated in a cadaver than any other available methods. Soft embalming methods have made the bodies more 'lifelike' and better suited for training. The widely accepted soft embalming techniques, including Thiel embalming, are designed for temperate climates. Their use in tropical locations has been found to be associated with poor short-term and long-term preservation of the bodies. In fact, adequate reports from tropical countries on effective methods for soft embalming are lacking. **Materials and Methods:** This article details the modifications made in the Thiel embalming technique over a period of 2 years which has enabled us to preserve the anatomical features of bodies in an optimal way for longer periods in tropical conditions. This study was carried out in a tertiary care referral centre located in a tropical climate zone. A total of 13 frozen and thawed cadavers were used over a period of 2 years for developing such soft embalming technique. The efficacy of the technique was tested using these cadavers for varying types of surgical exercises on multiple occasions. **Results:** The conventionally described technique of Thiel embalming did not provide desired results. Hence, various modifications to this technique were instituted which helped us to get superior quality of soft-embalmed cadavers. In the final year, these cadavers were used successfully for workshops in flap dissection. Head and neck access surgery, arthroscopic and laparoscopic procedures as well as mock face and hand transplant dissections. **Conclusions:** The Thiel embalming technique for obtaining soft embalmed cadavers, even though found to be best in many centres in the world, has not been found to be suitable to tropical weather. By modifying it, we have succeeded in developing a technique suitable to the tropical weather. This technique yields cadavers suitable for various surgical simulation exercises. This technique also allows the body to be optimally used over several months in multiple occasions. These modifications are very

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simple and have been described in detail enabling it to be adopted by any surgical skill laboratory in the tropical countries.

## KEY WORDS

Cadaver dissection; flap harvest course; soft embalming; Thiel embalming

## INTRODUCTION

With the advent of newer surgical and interventional radiological techniques, improved methods of surgical education for trainees as well as practising specialists become imperative.<sup>[1]</sup> Amongst the various methods that are currently used for surgical training, simulating surgery in human cadavers is the closest to actual practice. It still remains the most effective means to impart anatomical knowledge during the undergraduate and postgraduate medical training period. Even though a fresh frozen and thawed body may be best in maintaining the structure and suppleness simulating the real life situation, lack of availability of such bodies and proper storage facilities, unsuitability for long-term use and above all, health safety hazards do not allow this method to be universally adopted.

Embalming is a chemical process that has been used to overcome the problem of long-term storage of cadavers and minimise health hazards. Traditional methods of anatomical embalming depended on the use of formalin, which allowed long-term structural preservation of organs, but often led to over-hardening, making it difficult for precise anatomical and surgical training. A major change was brought in by the introduction of the technique of 'soft embalming' by Prof. Walter Thiel. This method has found acceptance in many centres for providing an excellent tool for surgical skill enhancement and anatomical dissection courses. However, its universal application has been found to be cumbersome due to the number of chemicals needed as well as the laborious process of preparing and storing the bodies. Moreover, Thiel's method, as well as the other soft embalming techniques, has been developed to suit temperate climates. When we tried following Thiel's method, the results in relation to long-term preservation were not satisfactory. Hence, we modified the technique to suit our tropical weather conditions, allowing us to store and use the cadavers multiple times.

This article deals with the method developed in our centre, which we believe can be used widely in tropical

countries, and allows multiple usages of bodies over a long period of time, even for procedures such as laparoscopic surgery.

## MATERIALS AND METHODS

The availability of donated bodies in our centre, similar to the situation prevailing in the rest of the country (India), is not very high. Hence, we have to depend on the cadavers of destitute patients who die in the nearby government-owned hospital and subsequently kept in the mortuary for disposal by the authorities concerned. These bodies are kept frozen at 4°C for at least 7 days, in case any claimants materialise, and if not, they are either disposed of or released for educational purposes by the government hospital authorities. These bodies are transferred to our own hospital mortuary, and embalming process is carried out over the subsequent few days.

We had been running surgical simulation courses periodically over several years using traditional formalin-embalmed cadavers. To improve the quality of tissues of the cadavers, we embarked on a soft embalming technique in 2012. The best method of soft embalming was described by Thiel.<sup>[1,2]</sup> When we were planning soft embalming of cadavers for our flap harvest and skull base surgery training courses, we felt that the method that most suited us was the Thiel technique. The methodology was available in the public domain, and it had been adopted by other centres indicating its reproducibility. This technique uses a mixture of 4-chloro-3-methylphenol, and various other salts for fixation, boric acid for disinfecting and ethylene glycol for the preservation of tissue plasticity, while the concentration of formalin is kept to a strict minimum (0.8%). Two stem solutions (A and B) are prepared. Using these two stem solutions as the base, the fluid for embalming and storage are constituted.

The details of the solutions are as follows:

- Stem solution A
  - Boric acid 3%: 9 kg
  - (mono-) Ethylene glycol 30%: 19 L

- Ammonium nitrate 20%: 12.6 kg
- Potassium nitrate 5%: 3.2 kg
- Water: 63.3 L
- Total: 100 L
- Stem solution B
  - (mono-) Ethylene glycol 10%: 18.2 L
  - 4-Chloro-3-methylphenol 1%: 1.8 kg
  - Total: 20 L
- Embalming solution
  - Stem solution A: 14.3 L
  - Stem solution B: 0.5 L
  - Formalin: 0.3 L
  - Sodium sulphite: 0.7 kg
  - Total: 15.8 L

Sodium sulphite and formalin are added just before perfusion. The final concentration of formaldehyde works out to <0.5%. The cadavers are perfused through the great saphenous vein. If this vein is difficult to find or to inject, the femoral or carotid artery is used. Fourteen litres of the embalming solution is perfused.

Subsequently, the bodies were to be immersed in tanks allowing them to mature for 4–6 weeks before they are used for dissection. The immersion solution was to be constituted as follows:

- (mono-) Ethylene glycol 10%: 71.9 L
- Formalin 2%: 14.4 L
- Stem solution B 2%: 14.4 L
- Boric acid 3%: 21.6 kg
- Ammonium nitrate 10%: 71.9 kg
- Potassium nitrate 5%: 36 kg
- Sodium sulphite 7%: 50 kg
- Water: 720 L
- Total: 1000.2 L.

After each use, the cadavers are to be vacuum sealed in plastic bags and kept at 4°C.

When we decided to use the Thiel technique, most daunting task was to procure the chemicals. During the 1<sup>st</sup> year, the decision for using this embalming technique was taken only a month before the start of the course. Because of the paucity of time between the procurement of the bodies and the surgical training programme, immersion of bodies in the tanks for maturation was not possible. Hence, after embalming, the bodies were kept at 4°C in a mortuary freezer. These were utilised for three sets of surgical exercises spaced out over 3 weekends. The bodies were replaced in the freezer after each workshop,

vacuum sealed in plastic bags as suggested in the original method. The major thrust area of the workshops was flap harvest from various regions of the body. One of the exercises conducted included endoscopic skull base surgery. The quality of structures in the cadaver was quite good and appreciated by all trainers and trainees. The soft and supple nature of the cadavers and the lack of odour were remarkable [Figure 1]. The only drawback was that by the end of 1 month, the bodies began to show signs of deterioration and decay indicating that it might not be good for long-term use.

The results of the embalming procedure encouraged us to continue with it, the next year also for more surgical workshops. Since enough time was available to procure the cadavers, we decided to go ahead with immersing them in specially made tanks after embalming, as suggested in the Thiel technique. Three cadavers were embalmed and kept in the immersion tanks. As a precaution, they were inspected every other day for their viability. To our dismay, we found that in a week's time, the bodies started decaying and were not retainable. We, therefore, had to conduct the surgical training programmes with conventional formalin-fixed bodies available in the anatomy department.

This experience made us explore other methods to preserve cadavers. We had to find ways to avoid the immersion aspect and sustain the bodies for a longer period in the freezer, allowing multiple uses. We decided to increase the formalin content to 4% from 0.8%. After the embalming, the body was kept at 4°C till they were used. A single cadaver was used to try this method out. The cadaver was kept stored for about 2 months and then was subjected to various procedures at weekly



Figure 1: Course trainees working on the soft and supple cadavers

intervals. These included raising skin, muscle and bone flaps [Figures 2-4], skull base and endoscopic sinus surgery [Figure 5], laparoscopic procedures [Figure 6], intraoral procedures and knee and shoulder arthroscopic surgical training [Figure 7]. A face transplant harvest also was carried out on the body [Figure 8]. The cadaver was transferred to the freezer each evening after the workshop. We found the quality of the cadaver to be excellent, being odourless and soft, which was retained for a long period (6 months). Based on this success, we adopted this method on four cadavers and conducted a series of surgical workshops. As expected, the bodies maintained their suppleness and were practically

odourless. The only slight drawbacks we observed were peeling of the skin and mummification of the areas where soft tissue flaps had been raised [Figure 9].

## DISCUSSION

Reznick and Macrae looking at the changing trends in teaching of surgical skills noted that out of the five modalities currently available, cadavers were most suitable in achieving the training goals.<sup>[3]</sup> These five

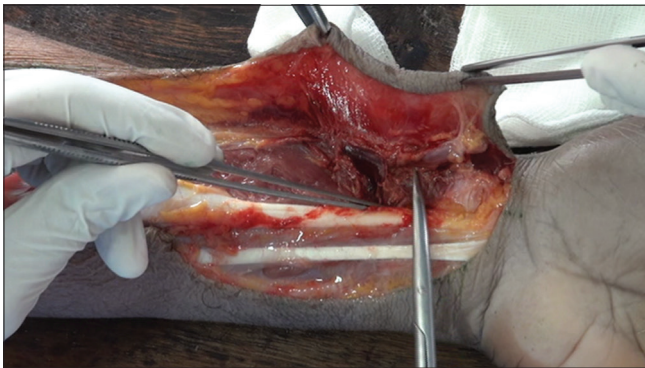


Figure 2: Radial artery forearm flap harvest

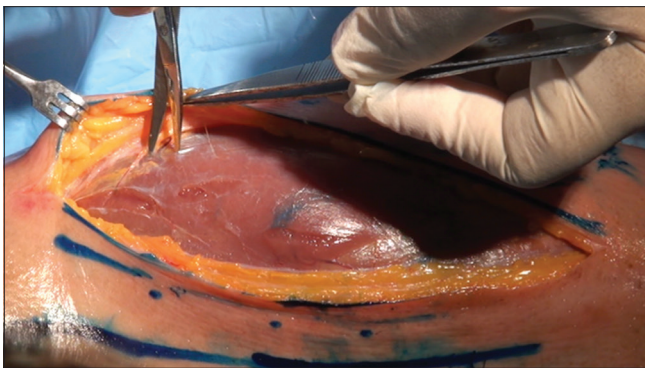


Figure 4: Perforator dissection on a Thiel embalmed cadaver



Figure 6: Laparoscopy in a Thiel embalmed cadaver



Figure 3: Pectoralis major myocutaneous flap harvest



Figure 5: Skull base Surgery



Figure 7: Shoulder arthroscopy in a Thiel embalmed cadaver



**Figure 8:** Face transplant harvest on a Thiel embalmed cadaver

modalities included bench models, live animals, cadavers, human performance simulators and virtual reality surgical simulators. Cadavers were termed as the only 'true' anatomical simulator currently available, offering high-fidelity platform and the only method allowing practice of the entire operation. A few drawbacks observed include lack of availability, poor compliance of tissues, difficulty for multiple session uses and chances of infection. The last two drawbacks had been addressed by traditional embalming methods using high formalin content. However, this method yields cadavers with poor tissue pliability and was associated with health hazards due to formalin vapours.<sup>[4]</sup>

Soft embalming techniques with lesser formalin content have been tried to overcome these issues. The method perfected by Prof. Thiel out of 30 years of experience in the Anatomisches Institut Karl-Franzens-Universitat, Graz, Austria, heralded a landmark change in the preparation of cadavers for surgical and anatomical training.<sup>[2,5]</sup> Popularly known as the Thiel embalming technique, this has been adopted by several centres.<sup>[6,7]</sup>

The Thiel embalming technique results in bodies that retain their softness for a prolonged period are relatively odourless and maintain precise anatomical features. However, it has some drawbacks, for example, technical difficulty in preparing the embalming solution, necessity of storing in tanks with special solution, necessity of vacuum sealing and storing in the freezer during multiple uses and the short duration during which the bodies can be used. A few modifications have subsequently been suggested to the original technique.<sup>[8]</sup>

During the 1<sup>st</sup> year of using this technique at our own centre, we did not have any major issues with the cadavers



**Figure 9:** Mummification of the areas of flap harvest

and could store them at 4°C in the freezer for a few weeks. However, towards the end of the series of workshops, by 4 weeks, the structures had started to become softer than what was desirable. We were not sure whether the body would remain unspoilt if they were kept frozen for a longer time. A longer period of storage would have been ideal since this would allow our cadaver procurement to proceed at a convenient pace. Hence, we decided to go ahead with the maturing part, i.e., keeping the bodies in the storage solution during the 2<sup>nd</sup> year. However, we faced abject failure within a week as we ended up with three cadavers putrefying in the tank.

We assumed that this was due to the ambient tropical temperature in our anatomy storage area. Ours is a tropical climate where room temperatures range from 27°C to 35°C with substantial humidity in the atmosphere. The Thiel storage technique had been developed and used in countries with temperate climate and did not appear suitable for temperatures like ours. We decided to change the strategy and increased the formalin content to 4%. The result was quite acceptable with regard to the suppleness of the tissues and absence of odour. We also decided to do away with the maturation process in the storage tank and concentrated on storage in 4-degree environment in the freezer. The storage did not involve special methods such as vacuum sealing, but only direct stacking of the bodies. The bodies were taken out of the freezer several times during the 6 months and subjected to multiple procedures. In spite of this, they did not show the signs of decaying which we observed in the 1<sup>st</sup> year, probably due to the increased formalin content. The only unsatisfactory aspect was the dry mummification of the areas that involved major soft tissue dissection, for example, harvest of radial forearm or anterolateral thigh flap. However, the other non-operated areas were not affected and allowed the performance of procedures as usual. The only explanation we could think of for this

mummification was extravasation and draining of the fluids from these dissected tissues.

It is our belief that this modified technique that we have adopted would be useful for soft embalming of cadavers in countries where the ambient temperature is relatively high. The usual problems associated with the storage of bodies in special fluids will not be encountered, and the requirement of chemicals is also lower. However, we would suggest that the surgical exercises necessitating extensive soft tissue dissection may be kept towards the latter part so that the mummification noted in these areas may not affect the rest of the exercises.

We would like to state that the use of this technique in routine anatomy teaching for undergraduate training has not been evaluated.

## CONCLUSIONS

The Thiel embalming technique for obtaining soft cadavers, even though found to be best in many centres in the world, has not been found to be suitable to tropical weather. By modifying it, we have succeeded in developing a technique suitable to the tropical weather. This technique yields cadavers suitable for various surgical simulation exercises. This technique also allows the body to be optimally used over several months in multiple occasions. These modifications are very simple and have been described in detail enabling it to be adopted by any surgical skill laboratory in the tropical countries. Further studies and refinements may be needed to adopt the same for undergraduate anatomy teaching.

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## Conflicts of interest

There are no conflicts of interest.

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