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Three Decades of Low Concentration Formalin and Theil Embalming: A Systematic Review

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ABSTRACT
Successful training of medical curriculum results in good doctors. Anatomy being the most important subject of medical training involves hands on dissection of cadavers. For study of undergraduate medical students and training and workshops to build efficient surgeons, properly preserved cadavers are required. Preservation of cadavers has been in prevalence since a long period of time and has seen a lot of transition and changes. This study was a small effort to study and compile some changes that cadaver preservation has seen over a period from 1992-2022 in terms of embalming fluids. Literature available of the said duration was studied and a systematic review was compiled of the low embalming fluids and Thiels embalming fluid in terms of softness, elasticity and fungal growth After systematic analysis of data pertaining to low concentration and theil embalming various chemical composition of the embalming fluid used was tabulated. Total of eight to ten chemical constituents were used. The presence or absence over a period of thirty years were marked in table 1. It was the correlated with the decreased concentration and usage of said embalming fluid formed. Theil and low concentration formalin was found to be very useful in hands on practice of surgeries but not cost effective and long standing for medical students in dissection.

INTRODUCTION

Anatomy is not just one of many subjects in medical education., it is the cornerstone upon which much of medicine is built. It fosters a comprehensive understanding of the human body necessary for effective clinical practice and specialization. Human body dissection plays a crucial role in anatomical study, offering several key benefits that are essential for developing competent healthcare professionals. Preservation techniques like formalin fixation, freezing, and plastination make these contributions possible by maintaining the physical and chemical properties of the body tissues. This allows for repeated use and long-term study, ensuring that bodies donated to medical science provide maximal educational and research value. It is already well known that formalin, though widely accepted and extensively used for body preservation, causes hardening of tissues when used in higher concentration and if used in lower concentration then tissues become prone to fungal growth and tissue destruction. Besides this, there is also a need for the most realistic and closest to living tissue like look. To achieve this goal, Walter Thiel first described an embalming method in 1992 based on a mixture of ammonium nitrate, boric acid and ethylene glycol (Thiel[1]) (Table 1). A large number of research data pertaining to various changes in Thiel concentrations used for preservation of human body is available. In this systematic review article, we will compare different concentrations of Thiel's adopted for preservation based on requirement, fixative used and the duration along with changes in tissues with various methods of preservation including preservatives with low concentration of formalin.

MATERIALS AND METHODS

In this systematic review article, research publications related to embalming methods, chemicals used were collected and studied by the authors. The comprehensive review extended over a period of 2 years. According to the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines[2] for 2020, articles were searched in four medical databases (PubMed, Google Scholar, Cochrane central register of clinical trials and Scopus), using the following key terms: 'cadaver dissection', 'chemicals used for embalming', 'soft embalming', 'Thiel embalming', 'newer techniques in cadaver embalming'. 'Low concentration formalin for embalming' articles hence collected were studied by the authors and findings reported. A total of 586 publications were included in the give time frame out of which 22 publications were further finalized for the current study and analyzed systematically.

Inclusion and Exclusion Criteria's: The present study included the original research articles, review articles, case reports, case series that studied the Thiels embalming techniques and different low concentrations of formalin used for embalming. Institutional Ethical Committee approval and informed consent were not needed as the study was a systematic review of the available literature and data already published with no direct involvement of human subjects or institutions.

RESULTS AND DISCUSSIONS

After detailed and thorough review of articles pertaining to our systematic review, the following result was compiled in a tabulated form. Formaldehyde, discovered by German chemist August Wilhelm von Hofmann[9] in 1869 is a milestone in the field of body preservation. The formaldehyde solution used in embalming is typically 37% formaldehyde[10], which can be diluted to any concentration with water. It is used as arterial fluid, cavity fluid, tank immersion fluid, cloth fluid. Major long-term preservation of cadaver is required in medical education as students need to learn anatomy through dissections. This exposes the students, medical teachers and dissection hall staff to the formaldehyde fumes for longer durations. Formalin is biodegradable, fast acting, cheap preservative with additional action of destroying germs. It simultaneously over rides the smell of putrefying proteins. Formalin has irritating odour, it causes hardening and discoloration of preserved tissues and it is a carcinogen[11]. Kunugita[12,13]. Reported geometric mean formaldehyde concentration to be 20-93 ppb in the anatomy laboratory before starting the anatomy dissecting. After beginning the dissecting, however, the highest geometric mean concentrations were 1012-1380 ppb causing"unusual thirst", "burning eyes", "itchy eyes", "bad feeling", "fatigue", etc. They suggested that medical schools should take more concrete measures to reduce exposure to formaldehyde[14,15]. Phenol based solutions[16,17] are effective in preventing bacterial and fungal growths. They help in fixing the tissues and stabilizing the cellular structures. They mask the unpleasant odour making the environment more tolerable for those working with the cadaver. They are relatively easy to prepare in large quantities, store at room temperature for extended period and use conveniently for medical institutions. They are pocket friendly. Introduction of Theil embalming solution in 1992[1] by Walter Theil was a major turning point in the field of life like human body specifically for surgical and related training practices. It allows natural colour of body with flexibility and plasticity of the body. Gradually in 2002 in Theil[3] modification there was introduction of significant amount of ethanol and total chemicals used to prepare changes to 10 in number. Theil method of embalming significantly reduces formalin concentration from 30%-37-0.4%-0.5%.

Table 1: Chemicals Used for Preparation of Low Concentration Formalin or Theil for Arterial Infusion/Embalming

S.no	Chemical Name	Theil[1]	Theil[3]	Eisma[4]	Hammer[5,6]	Reddy[7]	Sadeesh[8]
1.	Formaldehyde	+	+	+	+	+	+
2.	Alcohol	------	+ Ethanol	+	---------	------	+ Methylated spirit
3.	Water	+ (Hot)	+ (Hot)	+ (Hot)	+ (Hot)	+(Hot)	---------
4.	Ammonium nitrate	+	+	+	+	+	---------
5.	Potassium nitrate	+	+	+	+	+	---------
6.	Glycerine	------	-----	-----	-----	----	---------
7.	Chlorocresol	+	+	+	+	+*	---------
8.	Boric acid	+	+	+	+	+	---------
9.	Sodium sulfite	+	------	------	------	+	---------
10.	Ethylene Glycol	+	-------	-------	-------	+	---------
11.	Propylene Glycol	-------	+	+	+	----	---------
12.	Morpholene	-------	+	+	-------	-----	---------
13.	Phenol	-----	-----	-----	-----	-----	+
14.	Glycerol	-----	-----	-----	-----	-----	+
15.	Thymol	-----	-----	-----	-----	-----	+
16.	Eosin	-----	-----	-----	-----	-----	+
	Total Number of chemical used	8	10	10	8	8	6

*(4 Chloro 3 methylphenol) was used by Reddy *et al.*

Table 2: Comparative Usage of Various Chemical Based Preservatives Used for Embalming

Method	Description	Chemicals Used	Application
Formaldehyde-Based	Traditional method using a formaldehyde solution injected into the circulatory system.	Formaldehyde, methanol, other solvents	Widely used in medical schools for preserving cadavers for dissection and long-term study.
Phenol-Based[16,18]	Uses phenol for its preservative and antifungal properties.	Phenol, formaldehyde, glycerin	Often chosen in warmer climates for its enhanced antifungal properties.
Alcohol-Based[17]	Employs alcohol to preserve the body.	Ethanol, isopropanol	Preferred in cases of formaldehyde allergies or sensitivities., less effective at preservation.
Glycerin-Based[5]	Utilizes glycerin to keep tissues supple.	Glycerin, phenol, alcohol	Used for smaller specimens and in veterinary anatomy for easier dissection.
Plastination[18]	Replaces water and fat in tissues with plastics.	Silicone, epoxy, or polyester resins	Creates durable, dry and odorless specimens ideal for detailed anatomical study without decay.
Thiel Method[1]	A modern approach providing natural appearance and flexibility.	Salts, boric acid, ethanol	Gaining popularity in Europe for surgical simulation due to its preservation of texture and color.

It retains tissue flexibility and natural colour allowing for realistic anatomical representation during dissection. Reduced toxicity compared to traditional formalin-based fluids, safer for students and instructors. Tissues remain pliable and can be re-hydrated as needed. Since then various chemicals in different proportions were prepared with modifications for embalming. (Table 2) showing Comparative usage of various chemical based preservatives used for embalming. Phenol based solution used by Kalanjati[19] had only 7.5% formalin in their cadaver preservation fluid which contained 500gms of phenol powder in 0.5 Liter tap water to prepare 16 Liter of solution which also contained glycerine. Low concentration formalin resulted in lighter coloration, thus morphology, consistency of muscles and internal organs of the cadaver were more elastic and drier but stood moist for longer duration. Luminal structures like vessels were also clearer. Cadaver showed no fungal growth. Cost cutting was an added advantage including lower time involvement, because diluted solution entered the lumen of the vessels faster (approx. 30 min faster)[20]. Eisma[4] used similar constituents as Theil protocol 2002. Hammer[5,6] used ethanol glycerin fixative and in comparison to modified theil it can be used for Dissection and histological processing. Theil processed bodies are more suitable for workshop and hands-on practices. Reddy[7] further made modification in theil embalming so that it can be used in tropical areas for longer duration. Simultaneously it is beneficial for flap dissection and head and neck surgery simulation exercises. Sadeesh[8] also reported similar conclusions, that low concentrations of formalin prevented the shrinkage of several organs as in liver, lung brain. It also maintained the form and structure of vessels, which became brittle and non-distinguishable from nerves in high concentration formalin preserved cadavers. But the mould growth could not be prevented with low concentration formalin preservatives. (Table 2) shows various chemical based preservatives used for embalming over a period of thirty years since usage of low concentration formalin[20,22] along with theil[21] and their various modifications.

CONCLUSION

Low formalin concentration formalin and Theil embalming are very costly and very tedious process. It requires meticulously trained professional for embalming as it requires a lot number of chemical constituents and it is a step wise process. Also it requires inflammable toxic corrosive chemicals which can be hazardous too. It is more useful in surgical

simulation exercises. It is comparatively less beneficial for long term usage for medical students for dissection purposes specially in hot humid tropical countries.

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