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Short Communication

Cadaver Preservation Methods for Human Anatomy Teaching; a Three-Dimensional Approach

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ABSTRACT

Anatomy is the foundation of education for majority of the healthcare professionals where the cadavers have proven to be a primary-choice modern day teaching tool to understand the different structures of the human body. According to available statistics from Sri Lanka, nearly 25,000 doctors are currently residing in the country with nearly 1200 doctors graduating each year. Their human anatomy training is based on Formaldehyde has preserved cadavers which has been the desired choice in majority of the teaching institutions as it is available at a relatively lower cost though having well documented health hazards, compared to the cadavers preserved in other techniques such as ethanol-glycerin, glutaraldehyde and thiel.

Several studies conducted across the world has indicated formaldehyde can cause constant irritation to the ENT pathway and induce occupational asthma, moreover it is considered as a "probable human carcinogen" which can cause leukemia if exposed in the long run. The quality of the tissue using formaldehyde is another major concern where commonly discoloration and changes to the histological features being observed over time. This article focuses on providing insights on the effectiveness of developing 3 - dimensional approach to evaluate different preservatives.

INTRODUCTION

Human cadavers are a low health hazardous, 3D individual which is variable, morbid, mortal and non-vital. Those have a high haptic experience quality though with low availability and moderate cost [1]. Cadavers are used by anatomists as educational tools in teaching medical undergraduates either by using prosected specimens' demonstrations or by allowing them to do dissections themselves [2]. In Sri Lanka 1200 doctors are graduating annually with main contributions from the 8 medical schools in the state and one in the defense University. Majority of the universities across the world and Sri Lanka use human cadavers as the first patient for medical students in the 1st year and continue demonstration classes until they have familiarized the human body [3]. Medical education syllabus has taken innovative pedagogical methods over the years with syllabuses and context being focused towards the current world necessities being the top most priorities [4].

Preserving dead human bodies is necessary to keep it safe from harm, decomposition and destruction. From the ancient time several means of preservation from freezing and desiccation like natural means to addition of powders and immersion in chemicals like artificial means have been used in preserving the bodies. In modern world this is done through addition of chemicals known as preservatives and several preservatives are been tested to select the best that preserves the bodies best in the life like state while making the least harm for the people using the preservative or the cadaver treated with the preservative [2].

Formaldehyde fixatives have been used widely for cadaver fixation in anatomy over the years; it has known to be one of excellent fixatives that have antiseptic and preservative actions which allow preservation of the human cadaver. However, in the recent decade questions have been raised the effects on health caused by formaldehyde as it has been found to be "carcinogenic for humans" [5].

Despite the changes being made, the use of formaldehyde on human cadavers has been continuously being implemented over generations. Several scientific findings over the years have identified alternative solutions such as thiel, glutaraldehyde and ethanol-glycerin have been tested to provide an alternative solution to formalin [6-7]. Although they are costlier than formaldehyde, there are increasing putative evidence coming up that these alternative options might prevents occupational health hazards.

NCI surveys have shown that increased exposure to formaldehyde could lead to leukemia, ENT illnesses and brain cancer if exposed too much [8-9]. Indoor air quality also has been identified to be lower with the use of formaldehyde increasing the risks of respiratory tract infections such as bronchitis, asthma and long-term throat infections [10].

Thiel preservation methods have been used as alternative for formaldehyde providing better results with increased tissue efficacy, quality and elasticity [11]. The Thiel fixation introduced by Walter Thiel has been unanimously accepted across several scientific communities to be the new alternative, where the soft-fix method produces near life like cadavers for teaching and training purposes making the quality of medical education improve further [12]. The upcoming generation of doctors in Sri Lanka will be able to use real-life like state human cadavers for learning which will mentally prepare them better to handle patients in real-life from the 1st year itself.

Glutaraldehyde is another fixative which is presumed to be one of the best in retaining cell structure and safety. This can be also used for DNA studies as the DNA damage caused by glutaraldehyde is limited compared to other preservatives such as paraformaldehyde and formaldehyde [13]. Furthermore, studies conducted by the Royal School of Physicians have identified that the glycerin and glutaraldehyde solutions are capable of being used in combination with formalin to minimize the health hazards and issues caused [14].

With several studies indicating that alternatives for formaldehyde have emerged over the past two decades, researchers and medical institutions globally have experimented using various methods. However, in the context of low- and middle-income countries this has not changed due to the economic costs involved in preserving the human cadavers.

This article highlights the 3-Dimensional (3D) approach using preservatives to be adapted in future research projects to provide a cost-effective and viable solution to these institutions.

FORMALDEHYDE PRESERVATION

Use of formaldehyde in persevering human cadavers is believed to have happened first in 1899 and it is the chemical of choice now for preserving human cadavers. Formaldehyde reacts with nucleic acids, proteins and lipids by inserting methylene ($-CH_2-$) bridges between nitrogens of adjacent nucleophiles, proteins and amines which result a fixation or tanning-type

action [15]. To react 100g of soluble protein completely, 4.0-4.8g formaldehyde will be needed while the amount is even higher for non-soluble protein [16] and the average protein content in a human is 164.4g/kg. Accordingly, an 80kg cadaver will require 1.4-1.7L of 37% common formaldehyde solution or 0.52-0.63kg pure formaldehyde to react with its approximate 13.12kg proteins. Therefore, 10L of solution with 5.2-6.3% concentration of formaldehyde is injected to the cadaver. These high concentrations of formaldehyde make the cadavers harden vigorously leading to dissection difficulties while excess amounts of free formaldehyde evaporators making air pollution [17]. This condition can be overcome by adding a concentration of 0.025M sodium pyrophosphate together with or without 0.001M concentration of magnesium chloride to keep muscles pliable and joints moveable [18].

THIEL'S PRESERVATION

Thiel's method is a substitute for formaldehyde use, introduced in 1992 by Walter Thiel. With this method it has been able to preserve the corpse with natural colors for prolonged time maintaining its plasticity, flexibility and texture. This is done by a solution being injected into the vessels and then immersed in a second solution for a set period of time. In this method cadavers are stored within a sealed container and with no preservation fluid. Also, the formula of this method uses only low concentrations of formaldehyde cutting off irritating or toxic gases. Therefore, this is a convenient and efficient way of handling cadavers. Thiel's method of cadaver fixation and preservation involves 3 processes namely fixation, disinfection and preservation. The basic components of the solutions used in this method are 4-chloro-3-methylphenol, ammonium nitrate, potassium nitrate, boric acid, sodium sulfite and monoethylene glycol [19]. To preserve a cadaver of weight 80kg according to Thiel's method, 14,300ml of Solution A made with 3g of boric acid, 30ml of ethylene glycol, 20g of ammonium nitrate, 5g of potassium nitrate and 100ml of hot water plus 500ml of Solution B made with 10ml of ethylene glycol and 1ml of 4-chloro-3-methylphenol is perfused into the cadavers through the carotid or femoral artery together with 300ml of formalin and 700g of sodium sulfite. Then the cadavers are stored in an immersion solution made with 10% (v/v) (mono-) ethylene glycol, 2% (v/v) of Solution B, 3% (w/v) boric acid, 5% (w/v) potassium nitrate, 10% (v/v) ammonium nitrate, 7% (w/v) sodium sulfite and 2% (v/v) formalin for an approximate of 6 months. There after zipper polyethylene bags are used to keep the cadavers and can be used for years [20-21].

ETHANOL (ALCOHOL) PRESERVATION

Ethanol is a widely used anti-infective agent and an alcoholic solvent in cadaver preservation. Additionally, it is good in washing out excessive formaldehyde. Though the action of ethanol in cadaver preservation is not exactly identified, it reversibly denatures the proteins when combined with glycerin by affecting the hydrate coat in protein tertiary structure while disrupting the hydrogen bridges [22]. Moreover, studies conducted till date have identified that 70% ethanol seems to be the ideal concentration required to preserve samples, this has less potency and chances to cause discomfort unlike the use of formaldehyde [23]. However due to the limitations and lack of data available on this method, researchers have refused to experiment cadavers with ethanol preservation method due to lack of findings published for evaluation.

EFFECTIVENESS OF THE 3D APPROACH

Most preservatives provide the protection and appearance required for the human cadaver, but none of them have been able to provide the consistency of histological findings. This is mainly due to different chemical additives present in each of the preservation techniques which emulsifies and thickens the tissues of the organs. In order to identify an effective approach, this model of 3D preservation technique can be incorporated in medical institutions. By using the three preservatives discussed, the most cost-efficient and effective preservative can be identified to provide a better presentation of the human cadavers to future stakeholders.

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