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Management of chemical health hazard fumes emitted during and after embalming procedure and its impact on medical students and embalmers

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Abstract:
The process of human cadaveric preservation uses diverse embalming formulas introduced in cadavers by means of various technical approaches. Successful embalming requires the use of adequate formulas and techniques to fulfil a long-term structural preservation and minimize shrinkage and any harmful toxic effects to personal and environment. Our aim in this study is to generate a high-quality embalming formula that generate superior embalming and to minimize chemical toxic fumes emitted that students and embalmers are exposed to. An altered low formaldehyde based formula was used in our laboratories and introduced in cadavers through arterial injection using gravity infusion pressure. Results indicate an even distribution of the formula observed exhibiting superior tissue quality and excellent joint flexibility. Final formaldehyde concentration within the embalmed cadavers was minimal. The ambient fumes detected were significantly reduced when compared with other formula's used complying with international permitted values. There was significant reduction in the symptoms the students complain about during and after contact with cadavers. We conclude that this modified formula yields a higher quality preserved cadavers with high flexibility and colour preservation. A reduction of the unwanted ambient hazardous toxic effects of formaldehyde and other chemical fumes was achieved.
Key-words: Formaldehyde, cadavers, exposure, embalming, environment,

1. Introduction:

The process of human cadaveric preservation uses diverse embalming formulas introduced in cadavers by means of various technical approaches (Romero-Siera et al 1983, Bajracharya & Magar 2006). Naturally, physical and chemical changes lead to alterations in the external and internal structures of corpuses (Bajracharya & Magar 2006). Embalming can stop these reactions and give us the time needed to study human corpuses, and could be considered as a suitable tool, especially as an anatomy teaching tool, in medical schools (Coleman & Kogan 1998). Accordingly, the requirements for a successful embalming of cadavers include a long-term structural preservation with minimal shrinkage and distortion, prevention of over-hardening while maintaining joint flexibility (Coleman & Kogan 1998, Whitehead & Savoia 2008). Regular embalmed cadavers prepared using conventional methods, exposes medical students, embalmers, and faculty members having contact with cadaveric materials to formaldehyde fumes that are proven to have diverse toxic effects (Bernstein et al 1984). The main aim is to generate final product free of the environmental biohazards potential especially when fumes of formaldehyde and phenol are emitted. It is now recognized that formaldehyde fumes exposure leads to many unwanted health hazards, including irritation, immunologically mediated sensitization, and carcinogenicity (Moore et al 1986, OSHA 1992). Formaldehyde can also cause nasal squamous cell carcinoma in experimental rats and has been recognized as an irritant for the mucous membranes of the respiratory tract and eyes (Edling et al 1985, Sterling et al 2000). In addition, many of the international Environmental Protection Agencies have listed formaldehyde as a possible human carcinogenic agent (Almaguer et al 1990, Lewis 1993).
The progress in achieving proper embalming formulas is the use of new additive chemicals that reduce the risk of formaldehyde fume exposure (Savoia & Whitehead 2008). Accordingly, researchers have introduced different embalming formulas containing a variety of chemicals to ensure preservation of human corpuses and avoid any unwanted harmful hazardous effects (Janczyk et al 2011, Russell & Carl 2005). Recently, formaldehyde is considered to be the most suitable chemical that can replace other heavy metals used earlier in the embalming formulas for the protection of embalmers (Russell & Carl 2005). Therefore, prudent practices should seek to minimize more formaldehyde fume exposure and thereafter reducing its unwanted harmful effects and others chemical used within embalming formula's which could be accomplished by using proper and balanced chemicals. It is well known that chemicals used in embalming play an important role in keeping the cadaver free from decomposition and ensuring maximum preservation that would be accomplished by minimizing the health and environmental hazards (Daksha 2008). In embalming process, disinfection is being the most important step that would ensure safety of personnel handling the remains. This step is considered the prime

issue when personal and the environment safety is to be concerned. To achieve this goal, various supplementary germicides are added to augment restoration (Burke & Sheffner 1978). Ref # 20
This study aimed to reduce the toxic effects caused by exposure to emitted chemical fumes, and, in particular, to overcome the various hazardous effects due to exposure to formaldehyde and maintain good preservation of cadavers.

2. Materials and Methods:

2.1. Embalming Formula

A modified embalming formula was prepared in our institution containing the following chemicals that are listed in table 1. A total volume of 44 Litters was made of this formula. The volume was placed in heavy duty container with tight cover. The container placed at 3 meters above the cadaveric level to ensure adequate gravity pressure. To accomplish a good flow distribution of the formula introduced throughout the upper and lower regions of the cadaver, wood blocks were placed under the shoulder and the lower lumbar regions. The formula was introduced over a period of 48 hours with close regular monitoring every 3 hours.

2.2. Cadaver preparation

Cadavers were shaved, washed with running water and soap, and the cadaver surface was disinfected using Dettol (A chemical composed of chloroxylenol 4.8% w/w, isopropyl alcohol 10% w/w, pine oil 10% w/w manufactured by Reckitt Benckiser, UK).

2.3. Arterial Embalming

2.4. Modern practice in embalming utilizes the so-called "arterial embalming" technique. This method involves the injection of the embalming formula into the cadaver's arterial system (Tutsch 1975). The cadavers were embalmed using four injection points – two common carotid arteries and two femoral arteries. The formula was introduced by means of gravity pressure using metal canolas that were tightly legated to the arterial ends. The other ends of the canolas were connected through polyethylene tubes of 0.5cm diameter to a plastic tank containing the embalming formula. The tanks were elevated 3 m above the cadaver's level to ensure a suitable gravity pressure equivalent to approximately 8–10 PSI (Pounds/Square Inch). Before the embalming fluid was introduced into the cadaver's vascular system, air was removed from the tubes to avoid any possible airlocks in the cadaver's vascular system. The embalming period lasted for 36–48 hours depending on the physical conditions of the cadaver and the ability of the cadavers to accept fluid in its own rate.

2.5. Dissecting room's ambient fume measurements:

The chemical fumes, particularly fumes emitted from formaldehyde, were measured and evaluated in three dissecting rooms and in two storage areas. This was performed using Miran. Sapph. IRe. Ambient Analyzer and were recorded as Parts Per Million (ppm). Formaldehyde fume measurements were carried out in three dissecting rooms containing at least two cadavers that were left air exposed for a minimum of 48 hours prior to any recordings. Miran recording apparatus was placed 1 meter above the cadaver's level and left for 24 hours with alternate recordings at one hour interval. Measurement of the exposed cadavers was repeated two times in a similar fashion for cadaver's that were embalmed using old and new altered formula. Chemical fumes ambient concentration was also measured in the halls connecting these rooms. All the values recorded were compared with the international occupational exposure limits.

2.6. Evaluation of student reactivity to chemical fume exposure

The outcome of this modified embalming formula was evaluated using a questionnaire that was distributed to two groups of medical students:

Group 1: Represents medical students (236) that were exposed for two hours to human cadaver's embalmed using standard (old) embalming formula used previously in our and other Anatomy departments.

Group 2: Represents medical students (543) that attends the Anatomy laboratory sessions and exposed for the same period of time to cadavers embalmed using the new altered embalming formula.

All students had attended or were still attending the Anatomy laboratory sessions at the Department of Anatomy at Jordan University of Science and Technology. The parameters investigated, which were included in this questionnaire are listed in Appendix 1. These parameters targeted a set of unpleasant symptoms complaint about by medical students during and after the Anatomy dissection sessions at any given time. Data obtained from the questionnaire and collected from both groups were plotted and analyzed using two-variant student's *t*-test.

3. Results:

3.1. Cadaver quality using our embalming formula

Normally, embalming formulas are made of chemical mixture containing high concentration of formaldehyde, which is usually diluted in water. Ethanol has been used in our formula, instead of water, which accelerates tissue saturation; and thus enhances tissue penetration and facilitates easier intercellular distribution of formaldehyde (Ikeda et al 1993). Although the amount of formaldehyde added to the formula is minimal, our observation indicated that a high quality of embalmed tissue and superior quality of preserved cadaver was obtained when compared with cadavers embalmed with old formula. The cadavers were saturated properly due to a slow diffusion rate using gravity infusion pressure enhances the penetration of the formula used into the deeper muscle groups and body cavities. Cadaver flexibility was observed to be elevated in all embalmed cadavers using the new altered formula and was noted even at the levels of small joints. In addition, tissue coloration was maintained to its natural appearance, which is attributed to the phenol and enhanced by the addition to the fabric softener to the formula.

3.3. Ambient chemical fumes analysis

Formaldehyde and other chemical fumes emitted throughout the process of embalming and during dissection were evaluated and measured. The readings obtained were found to be below the values permitted by the international standard requirements, as shown in Table 2. The detected fume values indicated that formaldehyde fumes were non-detected (ND) in most of the dissecting rooms (Table 2). These recordings were further evaluated when more than one cadaver was present in one dissecting room that was left exposed for more than 48 hours. The readings obtained were also lower than those permitted by the international standard requirements. Thus, we can conclude that chemical fumes emitted from embalming cadavers were reduced when using this modified formula. As a result, it can be emphasized that this new embalming formula and technique used in our laboratories is more adequate and ambient-safe.

3.4. Students' reactive exposure evaluation

The laboratory ambient exposure was evaluated by medical students who were exposed to cadavers during the laboratory sessions. This was done using a questionnaire (Appendix 1) handed to the two students group. Students from both the groups were exposed to cadavers for 2 hours, representing the time of each laboratory session, and twice every week, as far as the parameters that were included in the questionnaire is concerned. A significant percentile reduction was observed in all the symptoms that the students complained, especially with respect to the unpleasant smell and nasal, skin, and eye irritations when the new embalming formula was introduced (Figure 1). Symptoms related to persisting odour and gastrointestinal irritations that were observed in the first group were found to be minimal with a significant reduction in the second group, indicating positive findings of this study (figure 1). As far as the student's participation is concerned, the number of students participating in this study varies and was increased in the second group when compared with the first one due to the acceptance policy of our university. The data were calculated in percentage of the student's compliments about each symptom explored by dividing the number of complaints students on the total number of participants.

Discussion:

Regular embalming formulas are made available by mixing various chemicals with different concentrations and dilute them in water, whereas the final formaldehyde concentration in these mixtures could reach as low as 5% (Janczyk et al 2011). Formulas containing high formaldehyde concentration have been used especially when treating problem related to cavity fluids (Ikeda et al 1993). It has been postulated that best results of embalming were accomplished when formulas were diluted in ethanol instead of water yielding superior cadaveric preservation reducing their toxic effect (Lewis 1993, Janczyk et al 2011, Ikeda et al 1993). For this embalming formula used in our laboratory was diluted in 95% ethanol leading to a final calculated formaldehyde concentration in the embalmed cadavers to be reduced reaching 0.5% (Sierocińska & Sierociński 1980). In addition, the problem of water replacement by the formula in cadavric tissues was managed when ethanol was used instead of water hence ethanol facilitate chemical penetration within the tissue (Savoia & Whitehead 2008, Nicholson & Samalia 2005). Thus, using this method along with our new altered embalming formula containing very low formaldehyde concentration, the risk of exposure to formaldehyde fumes and other chemical components was minimized (Williams et al 1984).

Low formaldehyde concentration used in our formula lead us to observe greater reduction in the ambient formaldehyde fume therefore its toxic effects. This was demonstrated by frequent measurements of the ambient formaldehyde concentration and comparison with the permitted values set by the occupational hazardous international institutions guidelines, as shown in Table 1. Harmful effects to chemical fumes exposure used in embalming due to inhalation ranges

from mild irritation of the upper respiratory tract and eyes, lacrimation, and even burning of nose and throat, to pulmonary oedema in severe cases as were demonstrated and pblished by the WHO (1998). Similar studies on formaldehyde vapour emission in embalming rooms clearly demonstrated that formaldehyde is mainly an upper respiratory irritant, causing eye and nose burns, sneezing, coughing, and headache (Bernstein et al 1984, Daksha 2008). The concentration of formaldehyde in the dissection room prior to the introduction of the new method and formula was found to be higher than that observed when using the new introduced formula (Sass et al 2007).

Additive chemicals are essential in maintaining superior quality of persevered cadavers. These chemicals include glycerine and carbolic acid that are able to react with other substances within the formula and thus increase its harmful effect. A superior quality and well-saturated cadavers were obtained using our embalming formula indicated by even saturated and distribution of the formula within the cadaveric tissues. The disinfectant property of our formula, especially when mixed with ethanol is enhanced and gives a great significance of the results obtained (Ikeda et al 1993). In fact, mould was not present in any region of the cadavers after 4 month storage period and when cadavers were exposed to ambient dissecting rooms for a long period of time. This is an additive positive accomplishment when our formula was used. All these signs were associated with the fact that amorphous distribution and saturation of the formula was accomplished not only in the deep muscle groups surrounding major arteries, but also in tissues within one region and in body cavities. Further, an unaltered tissue colouration and a maximum formula saturation were achieved due to the usage of adequate potassium acetate concentration that was added to the formula to ensure appropriate natural tissue colouring. This was proven by the fact that separation between tissue and fascia during dissection was easily accomplished, indicating adequate saturation and diffusion process. We believe that tissue saturation and formula distribution within the tissue were accomplished due to the fact that ethanol can facilitate easy replacement of body water with formaldehyde and eventually evaporate (Savoia et al 2008, Perkins & Kimbrough 1985).
During the embalming process, one of the important signs that indicate the effectiveness of the process is the appearance of whitish spots on the cadaver's skin. If the embalming process is adequate, these spots will disappear without a trace by the end of the embalming time. This is considered to be a positive sign and a good indicator of a successful embalming process. In addition, this sign indicates that the cadaver had received an adequate amount of the formula within the designated period of time as a result of tissue saturation. The disappearances of these spots were clearly observed in our study and had accoutred within several hours without a trace after embalming process was ended. This disappearance indicated that the embalming process was successful when the embalming formula was introduced into the corpuses using gravity infusion pressure. It was noted Perkins & Kimbrough (1985) that gravity infusion pressure could increase the ability of chemical components of the formula to be evenly distributed throughout the cadaver without the risk of arterial leakage. This fact was noted her in contrast with other embalming methods using pressurized pump infusions accomplishing embalming in a short period where constant leakage was observed (Chiu & Shaw 2010, Coleman & Kogan 1998).
In order to provide tissue softening, improve tissue colouration and reduce the unpleasant odour of the fumes emitted, fabric softener was added to our formula. In addition to tissue clarity, tissues exhibit softer texture and was easy to handle a fact that was demonstrated earlier by Bajracharya & Magar (2006). The irritant smell generated from the chemicals used in any embalming formula is considered a major issue in embalming. This problem can be partly prevented by the addition of fabric softener which can eliminate irritant smell of chemicals, especially phenol. This new additives has not been previously used as a part of any regular standard embalming formula. However, it has been reported the usage of this class of chemicals during restoration of the neglected dissected specimens into their original condition by soaking specimens for more than 24 hours in a standard softener solution (Bajracharya & Magar 2006, Chiu & Shaw 2010). Furthermore, flexibility and degree of mobility of joints of different regions, such as neck, shoulder, and pelvic girdles, were also accomplished when compared with cadavers used by us previously embalmed with a regular embalming formula. Currently, no explanation concerning the mechanism through which fabric softener acts in combination with other chemicals when used for embalming could be provided. Additionally, the salt based composition of this softener can play an important role in facilitating diffusion and cellular exchange with the chemicals components of the formula especially formaldehyde (Janczyk et al 2011).

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Table 1

Chemical used	**Concentrations**	**Percentage**
Potassium acetate (saturated solution in H_2O)	500 ml	2.27 %
Dettol	600 ml	2.72 %
Phenol (carbolic acid)	500 ml	2.27 %
Formalin (37% Formaldehyde final concentration to total volume).	500 ml	2.27 %
Propylene glycol (Glycerin)	1000 ml	4.55 %
Fabric Softener (DHTDMAC) (Dihydrogenated Tallow Dimethyl Ammonium Chloride).	6500 ml	29.5 %
Total chemical volume	9600 ml	43.6 %
Ethanol 95%	12400 ml	56.4 %
Total formula volume	22000 ml	100 %

Description of the above table (1):
Table 1 represents the components of the new altered embalming formula used in our laboratory for human cadaveric embalming. The percentage of each chemical concentration presented as total amount of the chemical divided by the total volume of the formula used.

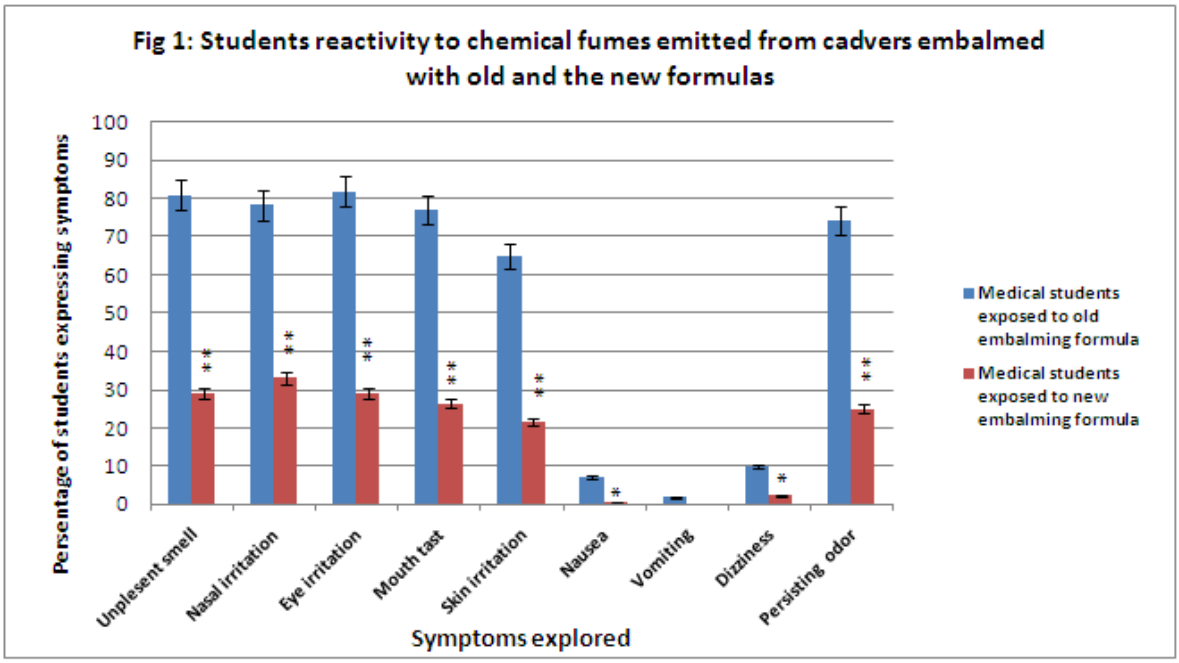
Table 2

ND: Not Detectable
ppm: Parts Per Million
NIOSH: National Institute of Occupational Safety and Health.
ACGIH: Occupational Safety and Health Administration
WHO: World Health Organization

Location	**Number of cadavers exposed to ambient rooms left for 48 hours prior to measurements.**	**Formaldéhyde ambiant fume measurement (ppm) Average readings of 2 consecutive days**		**Occupational exposure measurements limits permitted for formaldehyde fumes (ppm)**
		Cadavers embalmed with the old embalming formula (ppm)	**Cadavers embalmed with the new embalming formula (ppm)**	
Dissecting room 1	**1**	**0.83**	**ND*** **	**NIOSH 0.016 ACGIH 0.300 WHO 0.050**
Dissecting room 2	**2**	**1.65**	**0.010***	
Dissecting room 3	**4**	**2.57**	**0.012***	
Cadavers storage area 2	**2**	**0.52**	**ND*** **	
Cadavers storage area 3	**2**	**1.53**	**ND*** **	
Connecting areas (hallway)	**None**	**0.49**	**ND*** **	

Description of the above table (2):
Table 2 represents dissecting and storage areas ambient fume continuous measured for 48 hours emitted from cadavers embalmed with the old and new embalming formulas in the morgue of the anatomy department at JUST. Recordings were done using Miran Sapph IRe Ambient Analyzer (ppm: "part per million"). Recordings were initiated prior to two days exposure of cadavers to ambient rooms in designated areas. The average values of 4 consecutive reading within a period of two days were compared with previously recorded ambient readings when similar numbers of embalmed cadavers using old formula were explored and found to be significantly reduced. Values were also compared with the international permitted measurements limits and found to be below the limits permitted.

Figure 1



Description of the above figure (1):
Figure 1 indicates the results of a questionnaire exploring symptoms of which medical student's complaint about during Anatomy laboratory sessions. One group of students were exposed to cadaver's embalmed using old formula and the others were exposed to cadaver's embalmed using new formula. A total of 9 parameters were investigated and data is expressed in percentage by dividing the number students with complaints on the total number of participants from each group. Results indicate significant reduction in the all symptoms investigated when both groups were investigated in favour of the method of embalming using our new formula. Two-variant student's *t*-test was used.

Appendix 1:

I. General questions:

1. Status:	**□ Medical student (5–6th year)**	**□ Medical student (2–3rd year).**
2. Clothing:	**□ Lab coat**	**□ No lab coat**
3. Head cover:	**□ Yes**	**□ No**
4. Exposure:	**□ One time/week**	**□ Two times/week**
5. Exposure: (Time/session)	**□ 1 hour**	**□ 2 hours**
6. Are (Place)	**□ Small dissecting room**	**□ large dissecting room**

II. Specific questions

Related to chemical and formalin fume exposure (cadaver's exposure):

A. During anatomy laboratory session

1.	2.	3.	4.	5.	6.	7.	8.	9.
Unpleasant smell □	Nasal irritation □	Eye irritation □	Mouth irritation □	Skin irritation □	Nausea □	Vomiting □	Dizziness □	Persisting and odour □

B. After anatomy laboratory session

1.	2.	3.	4.	5.	6.	7.	8.	9.
Unpleasant smell □	Nasal irritation □	Eye irritation □	Mouth irritation □	Skin irritation □	Nausea □	Vomiting □	Dizziness □	Persisting hand odour □

Description of the above Appendix (1)

A questionnaire distributed among medical students representing two groups. This questionnaire included a general informational section concerning with students status, clothing, and the frequency of laboratory attendance. The second specific informational section deals with diversified symptoms that the medical students complaint off during and after anatomy laboratory sessions. This section also evaluates the direct effects of chemical exposure on students.

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