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Correspondence

Embalming fluids

Concern has recently been expressed about formaldehyde levels in dissecting rooms and embalming suites in anatomy departments throughout the United Kingdom, mainly as a consequence of the introduction of the Control of Substances Hazardous to Health (COSHH) regulations. We have therefore undertaken a survey of the difficulties experienced by a number of anatomy departments in the country and have investigated ways of alleviating the problem, the conclusions of which are presented below.

E. O'SULLIVAN AND B. S. MITCHELL
Human Morphology,
University of Southampton, UK.

An improved composition for embalming fluid to preserve cadavers for anatomy teaching in the United Kingdom

INTRODUCTION

Understanding the construction of the human body has fascinated mankind for centuries, and anatomical description has been greatly facilitated by use of embalming procedures utilising fixatives for preservation of the 'fabric' of the body in as lifelike a state as possible. Prior to the nineteenth century various heavy metal salts were used for preservation, including arsenic, zinc or lead, but formaldehyde was not used until the latter part of the nineteenth century (Mayer, 1990). Little has been written about modern embalming methods for anatomy teaching purposes aside from the abstract published by Logan (1983).

Concern has been expressed in relation to the occupational exposure to formaldehyde by workers in anatomical laboratories (Papst, 1987) and this was recently emphasised by Hayes et al. (1990), whose findings indicated that there was a greater than average incidence of malignancies of the haemopoietic and lymphoid systems amongst anatomists and embalmers in the United States. Modern embalming techniques for anatomical purposes have recently become subject to the Control of Substances Hazardous to Health (COSHH) regulations (Health and Safety Executive, 1990) in the UK, which limit formaldehyde exposure time for personnel involved with embalming procedures. Methods to remove formaldehyde by its substitution with phenoxyethanol have been tried (Frølich et al. 1984), although without widespread adoption in the UK at least. This may be because of the lengthy process involved, as well as the large quantities of phenoxyethanol required.

There is a need, therefore, for an overview of current practice in the UK and for an investigation of the importance of formaldehyde in the embalming process. We here report an investigation of ways of reducing the levels of formaldehyde, without impairment of fixation, in the procedures so as to meet the requirement of the COSHH regulations (UK), and to improve efficiency of embalming procedures.

MATERIALS AND METHODS

Questionnaire

A questionnaire was sent to 25 medical schools throughout the UK to determine the composition of the embalming fluids used by individual schools. Questions requested information on (1) composition of the embalming fluid used; (2) whether formaldehyde vapour was monitored during the embalming procedure and, if so, by which method; (3) details of the procedure used for embalming; (4) whether the embalming fluid was buffered; and (5) whether tap water or distilled water was used in embalming fluid.

Formaldehyde vapour determination

Formaldehyde vapour level was measured in the dissecting room and embalming suite by use of the Gastec passive Dositube 91b (Detectawl), as supplied by the University of Southampton Safety Office. Each dositube has a calibrated scale from 0 to 20 along its side, indicating parts per million of air of formaldehyde vapour. A change in colour in a white test strip indicates the formaldehyde vapour level in parts per million (ppm) of air. Dositubes were attached to the lapels of embalmers and dissectors, and readings taken every 30 min throughout embalming or dissecting procedures. In both these types of procedures activities were not continuous, but were carried out for comparable periods of time in all experiments.

Embalming procedure

Cannulae were inserted either into the common carotid artery, or the femoral artery. Embalming fluid was introduced using a total volume of 12–18 l with a mechanical pump (Dodge Chemical Co.) at a pressure not exceeding 0.21 kg cm^{-2}. The composition of the original Southampton

Correspondence to Dr B. S. Mitchell, Human Morphology, Faculty of Medicine, University of Southampton, Biomedical Sciences Building, Bassett Crescent East, Southampton SO9 3TU, UK.

Table 1. *Concentrations of the various components of the embalming fluids.*

Component	Original	Expt 1	Expt 2	Expt 3
Formaldehyde	106 ml/l	53 ml/l	106 ml/l	53 ml/l
IMS	425 ml/l	625 ml/l	625 ml/l	625 ml/l
Distilled water	248 ml/l*	101 ml/l	48 ml/l	48 ml/l
Phenol	67 g/l	67 g/l	67 g/l	67 g/l
Glycerol	154 ml/l	154 ml/l	154 ml/l	207 ml/l
pH buffered		7.7	7.9	7.7
pH unbuffered		6.3	6.6	6.5

IMS, industrial methylated spirit; * tap water.

embalming fluid is shown in Table 1. After supplementary local injections of embalming fluid, the total volume of fluid used was between 14 and 25 l, depending on the size of the subject and how effective the pumped embalming had been. A pilot experiment showed that the common carotid artery route of cannula insertion allowed a greater volume of embalming fluid to be introduced than by use of the femoral route. As a consequence there was a reduction in the need for supplementary injections, which in any case is a less effective method for total body embalming (personal observations). The choice of route may, in any event, be determined by the dissection requirements after embalming. After embalming was completed the cadaver was sealed in polythene sheeting and left for approximately 6 wk in cold storage before examination.

Method for assessing embalmed cadaver quality

A subjective measure of effectiveness of embalming, in relation to ease of dissection and of preservation, was made for each of the cadavers. Similar dissections were carried out on all cadavers examined, which involved flaying the anterior abdominal wall and examination of the musculature, and opening the abdominal wall by a cruciate incision to examine the abdominal viscera.

Embalming fluid composition experiments

Embalming was carried out using the Southampton original recipe and 3 other experimental fluids of different composition (Table 1). Each experimental embalming was referred to as experiment 1, 2 or 3. In all 3 experiments the fluid was made up in 2 versions, unbuffered and buffered, using 0.075 M phosphate buffer (pH 7.4). Formaldehyde works best at pH 7.3–7.8, hence it was predicted that if embalming fluid could be buffered to this range of values, more efficient embalming would be achieved. Accordingly, the pH of the various embalming fluids used was determined.

RESULTS

Questionnaire

Although the same constituents could be identified in all the embalming fluid recipes from the 16 UK medical schools that replied to the questionnaire, there was remarkable variation in the proportions of these constituents. Figure 1 shows a bar diagram of the data sorted according to the formaldehyde component. Those recipes associated with mould on specimens have been indicated. The original Southampton recipe is also indicated.

Formaldehyde vapour level determination in original Southampton recipe

Using the original Southampton recipe for embalming, 2 fluid readings of formaldehyde vapour levels were obtained using the dositube indicators as follows: 1.29 ppm, 1.43 ppm. Both these readings were obtained over a 4 h period for embalming and both were above the levels prescribed by COSHH regulations.

Formaldehyde vapour level determination in experimental fluid composition embalmings

Results of dositube readings are shown in Table 2. In all instances the readings were within the limits set by the COSHH regulations. In experiment 3, replicate results were obtained as well as the results from a different operative.

Embalmed cadaver quality in experimental embalmings

Experiments 1, 2 and 3. All cadavers appeared to be adequately fixed; the muscles were soft and pink. Subcutaneous adipose tissues appeared very white. The fascia was strong and easy to remove. The deeper tissues and organs appeared to be well fixed, and the bodies proved easy to dissect.

In all 3 experiments the buffered embalming fluid became cloudy during preparation and it proved impossible to dissolve all the buffer salts; because of the presence of the undissolved salts, the cannulae were often blocked. Evidence that the buffering was ineffective could be deduced from the fact that the pH changed from that of the original buffer

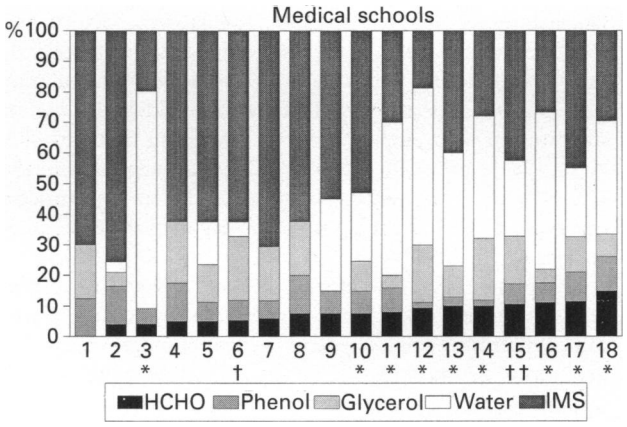

Fig. 1. Proportions of embalming fluids used by 16 anatomy departments and 2 formulae (original formula and the formula from experimental fluid 3) as used by the Department of Human Morphology at Southampton University Medical School. * Mould; † new Southampton formula; ‡ old Southampton formula.

Table 2. *Dositube readings of formaldehyde vapour in the experimental embalmings and subsequent dissection, and duration of procedures*

Expt no.	Embalm	Dissect	Embalm*	Dissect*	Embalm†
1U	0.67 ppm 1.5 h	0.53 ppm 4.75 h			
1B	1.0 ppm 2.5 h	0.88 ppm 4 h			
2U	1.0 ppm 1.5 h	1.14 ppm 3.5 h			
2B	0.66 ppm 4.5 h	1.5 ppm 4 h			
3U	0.2 ppm 2.5 h	0.29 ppm 3.5 h	0.33 ppm 3 h	0.33 ppm 3 h	0.4 ppm 5 h
3B	0.25 ppm 2.5 h	0.6 ppm 4 h	0.42 ppm 4.75 h	0.43 ppm 4 h	

* Repeat values, same operative; † repeat values, different operative; U, unbuffered embalming fluid; B, buffered embalming fluid.

solution to the pH of the embalming fluid. No difference in embalming quality was observed, however, irrespective of the composition of the embalming fluid used.

CONCLUSIONS

Examinations of the composition of the embalming fluids from the 16 UK medical schools that replied to our questionnaire revealed wide variation in the proportions, but not the identity, of the constituents of the embalming fluids. The major component of at least 10 of the schools was industrial methylated spirit (IMS), with tap water next. Generally, there appeared to be an inverse relationship between the content of IMS and water. All schools used tap water, although at Southampton distilled water was substituted for tap water and this has appeared to eradicate the mould problems. In all instances, except one, formaldehyde figured in the composition. The combination of the IMS and the formaldehyde together fulfilled the requirement for fixation in the embalming fluid. Proportions of glycerol also varied widely, bearing no relationship to the other components. The proportion of phenol appeared to be a constant feature in all formulae, reflecting its important disinfectant quality. There was always a requirement for sufficient fluid volume to dissolve the phenol and to ensure that the glycerol was adequately mixed with the other components of the fluid. The proportions of water in the fluids appeared to relate to the appearance of mould on the stored cadavers or dissected specimens. In all the schools with greater than 25% water in the fluid, mould was reportedly a problem. A major advantage of increasing water content is, of course, cost saving. Thus avoiding excessive proportions of water in embalming fluid should obviate the need for special treatment to deal with mould growth. Although mould growth was reported by a number of schools, no information was gained about quality of embalmed cadavers, aside from the assumption that they were of sufficient quality to perform anatomical examinations. It is also possible to correlate mould growth with high proportions of formaldehyde and low proportions of IMS. This may imply that high formaldehyde or low IMS proportions, and thus higher water content, could result in mould growth. More important factors may, however, be the use of tap water in embalming fluids and the subsequent cadaver storage conditions.

The results of varying the composition of embalming fluids in experiments 1–3 indicated that apparently good fixation could be obtained with any of the formulae, even where there was a low proportion of formaldehyde. Buffering did not appear to confer any obvious advantage on the embalming outcome and undissolved buffer salts often blocked the cannula. Duplication of results did not reveal any wide variation, even if using a different operative.

In experiment 3, the proportion of glycerol was increased to compensate for the hardening effect of the high IMS concentration and the low proportion of water. This also had the advantage of helping to prevent fat from leaching out from the body tissues.

It was concluded that the formaldehyde proportion could be reduced, and IMS proportion raised, resulting in effective embalming. Furthermore, the formaldehyde vapour levels in procedures using reduced formaldehyde concentrations were within the limits prescribed by the COSHH regulations ($\leqslant 1.00$ ppm) (which the Southampton original formula was not, nor indeed were at least some of the formulae of other schools). The formula recommended in experiment 3, with reduced formaldehyde and distilled water, and increased glycerol and IMS resulted in improved tissue preservation with a more natural coloration. Since the initial experiments were carried out, cadaveric material embalmed using the formula in experiment 3 has been retained for up to 2.5 years, and there has been no obvious deterioration in preservation. The typical 'wear and tear' sustained by prosected material by student handling has not results in specimen damage, over and above that which might be expected in the usual lifetime of an anatomy course for medical undergraduates.

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