Original Article

Indian Journal of Anatomy
Volume 9 Number 1, January – March 2020
DOI: http://dx.doi.org/10.21088/ija.2320.0022.9120.5

Comparative Study of Formalin Solution and Saturated Salt Solution for Embalming Cadavers for Surgical Skills Training

Rachna Gulati[1], Manish S Ahuja[2], Vijay Langer[3], Parikshat Gopal[4], Shaifaly M Rustagi[5], Vandana Dave[6]

How to cite this article:
Rachna Gulati, Manish S Ahuja, Vijay Langer et al. Comparative Study of Formalin Solution and Saturated Salt Solution for Embalming Cadavers for Surgical Skills Training. Indian J Anat. 2020;9(1):33-37.

Author's Affiliation: [1]Tutor, Dept of Pathology, [2]Professor [5]Associate Professor [6]Tutor, Dept of Anatomy, [4]Associate Professor, Dept of Orthopaedics, Army College of Medical Sciences (ACMS), New Delhi 110010, India, [3]Professor, Dept of Surgery, Army Hospital Research And Referral 110010, Delhi, India.

Corresponding Author: Manish S Ahuja, Professor, Department of Anatomy, Army College of Medical Sciences, Delhi Cantt 110010, India.

E-mail: msahujaone@gmail.com

Received 29.11.2019 | **Accepted** 01.01.2020

Abstract

Context: Surgical techniques have advanced rapidly over the years. Surgeons need to update themselves with these advances. Many surgeons also feel the need to hone their surgical skills so as to achieve best possible management of their patients. To facilitate this, Surgical Workshops (SWs) are organized in medical colleges. For these workshops to be effective, it is necessary that cadavers used in these workshops be embalmed in such a way that they resemble the body in natural state as far as possible.

Aims: To compare the two embalming methods–formal in solution and saturated salt solution in terms of (a) Sterility of body tissue/fluids achieved; (b) Range of motion in joints postembalming; (c) Ease of performing incision on abdomen.

Settings and Design: A total of 16 cadavers were taken for this study. These were all donated bodies between the age group 50–80 years.

Materials and Methods: These cadavers were divided into Two Groups: Group A and Group B. Each Group had four male and four female cadavers. Group A was embalmed using formalin solution and Group B was embalmed Saturated Salt Solution (SSS). Bacterial culture tests and measurement of ranges of motion were conducted for each cadaver. In addition, incision followed by suture were performed in the cadavers.

Statistical analysis used: Mann Whitney *U* test.

Results: The SSS method had a sufficient antibiotic effect and produced cadavers with flexible joints and a high tissue quality suitable for surgical workshops. The surgeons found the cadavers embalmed by the SSS method to have a higher range of mobility than those embalmed by the formalin method.

Conclusions: Cadavers embalmed by the SSS method are optimum for SWs. This method is simple, carries a low infectious risk, and is relatively of low cost, enabling a wider use of cadavers for training in surgical techniques.

Keywords: Cadaver; Embalmed; Formalin; Salt; Surgical; Workshop.

Introduction

Embalming of human body has been practiced since ancient times. Biblical texts refer to this practice, and Egyptians are known to have successfully embalmed bodies centuries ago.[1] Advances in surgical techniques and procedures necessitate that specialists in surgery and allied fields should train in the new techniques and try to master them.[2]

Various options are available to facilitate this training. These include use of live animals on whom surgical techniques can be practiced under anesthesia. This raises ethical issues which cannot be brushed aside. Also, anatomy of mammals may not exactly resemble that of humans. The other option is to use simulators and mannequins. These have limited utility for practicing surgical techniques, though they have proved effective in training of paramedical staff in procedures like cardiopulmonary resuscitation.[3–5]

Thus, the best resource for training of doctors in surgical techniques in specialties like surgery, orthopedics and ENT is the cadaver. Cadavers used for practicing and improving upon surgical techniques should mimic the living human body as far as possible. Proper preservation of cadavers is therefore very important.[6] Fresh or fresh frozen cadavers have been used for surgical workshops. They have advantages: Exhibit life-like color, retention of softness and good pliability. But they also have drawbacks: There is requirement of freezers for storage and they can be used for limited period of time due to put refaction that occurs on thawing. There is also the risk of contracting infection as these cadavers are not embalmed.[7]

Thus, the best resource for surgical skills workshop is the embalmed cadaver. Embalming fluids facilitate preservation of organs and tissues. An ideal embalming fluid should achieve the following: (a) Long-term preservation of the cadaver, (b) Prevent hardening of tissues, (c) Retain natural color and texture of tissues and organs, (d) Prevent excessive dessication and (e) Destroy bacteria and prevent their growth.[8]

Formalin Solution (FS) has been extensively used for embalming cadavers for more than a century now – either alone or in combination with other fluids. Formalin effectively coagulates tissue proteins, thus, preventing their degeneration. It is also effective as a bactericidal. But it also has drawbacks. It causes tissues and organs to become very rigid, thus, robbing the cadaver of pliability so, necessary for practicing surgical techniques.[9,10]

Keeping the drawbacks of formalin solution and the limitations of frozen cadavers in view, it is desirable that alternative methods of preserving cadavers be explored, especially for training in surgical techniques through dissection workshops.

Saturated Salt Solution (SSS) is one such material whose utility and effectiveness to preserve cadavers esp with regard to surgical workshops needs to be explored. It has been tried earlier, but only to preserve cadavers for dissection and teaching purpose.[11]

Objectives

To compare the two embalming methods in terms of (a) Range of motion in joints postembalming; (b) Sterility of body tissue/fluids achieved and (c) Ease of performing incision on abdomen.

Materials and Methods

A total of 16 cadavers were taken for this study. These were all donated bodies between the age group 50 and 80 years. These were divided into Two Groups: Group A and Group B. Each Group had four male and four female cadavers. Group A was embalmed using formalin solution and Group B was embalmed Saturated Salt Solution (SSS) methods. Bacterial culture tests and measurement of ranges of motion were conducted for each cadaver. In addition, incision followed by suture were performed in the cadavers.

The composition of these two solutions is as under:

(a) Formalin Solution (FS)

	Ingredient	Amount
(i)	40% Formaldehyde	6 L
(ii)	Ethyl Alcohol	0.4 L
(iii)	Glycerine	1 L
(iv)	Phenol	0.2 L
(v)	Water	12.4 L
	Total	20 L

(b) Saturated Salt Solution (SSS)

	Ingredient	Amount
(i)	Sodium chloride	7 kg
(ii)	40% Formaldehyde	0.5 L
(iii)	Ethyl Alcohol	0.4 L
(iv)	Glycerine	1 L
(v)	Phenol	0.2 L
(vi)	Water	Added to dissolve sodium chloride till solution becomes 20 litres
	Total	20 L

Embalming was done through the common carotid artery. An incision measuring 3 cm was made on anterior border of sternocleidomastoid (SCM) just below upper margin of thyroid cartilage. Around 5 L of embalming fluid was injected under pressure. The canula was left in place overnight and removed the next day. After this the common carotid artery was ligated and the incision was closed. Once embalming was completed, the cadaver was shifted back to a tank having phenoxyethanol as preservative.

Bacterial culture tests: These tests were conducted to see the level of sterility attained in the cadavers after embalming by the two methods. Samples were taken from:

(a) *Pharynx*: Through pharyngeal cotton swab.

(b) *Pleural fluid*: By opening up seventh intercostal space on both sides and taking swab.

(c) *Peritoneal fluid*: Incision was made in right iliac fossa and peritoneal swab taken.

The swabs used were sterile. The incisions for pleural and peritoneal fluid were made after sterilizing the skin over the region so that no infection is introduced. These samples were taken before embalming and again on 15 days after embalming.

Measurement of range of movement (ROM) of Joints: Orthopedic surgeon measured ROM of joints of both right and left side. Comparison was made between cadavers embalmed by FS *vs* those embalmed using SSS. A standard goniometer was used to test range of movement. Shoulder, elbow, hip and knee joints were tested.

Subjective assessment of each embalming method: This assessment was done by surgical specialist and orthopedic surgeon. This included:

(a) Paramedian incision on abdomen.

(b) Exposure of femoral vessels.

(c) Incision over gluteus maximus.

Results

1. *Bacterial culture tests*: The Formalin Solution (FS) embalmed cadavers revealed no bacterial growth after 15 days. Therefore, FS proved to be 100% effective in killing bacteria. The SSS embalmed cadavers revealed the following:

(a) In four out of eight cadavers there was no bacterial growth after 15 days.

(b) In one cadaver, there was one colony formation from pharyngeal swab culture.

(c) In one cadaver, one colony was formed from peritoneal fluid.

Thus, SSS was not as effective as FS in sterilizing the cadavers. However, only one colony each is grown from pharynx and peritoneal fluid in two cadavers.

2. *Range of Movement (ROM) at Joints*: The Mann Whitney *U* test was used to analyze the data obtained for Range of Motion (RoM). The RoM shows significant difference between Formalin Solution and Saturated Salt Solution. The data and results are summarized in Tables 1–4.

3. *Assessment by surgeons and orthopedic surgeons*:

Visual and tactile assessments by surgeons revealed that FS embalmed cadavers differed from living patients quite significantly: there was much more rigidity of tissues and skin. The SSS embalmed cadavers resembled the living patient much more in terms of pliability of tissue and flexibility of skin. The range of movement of joints was higher in SSS embalmed cadavers than in FS embalmed cadavers. The joints tested were shoulder, elbow, hip and knee.

Table 1: Range of Motion (RoM) at various joints in Formalin solution embalmed and Saturated Salt Solution embalmed cadavers. The legends are as per Table 2.

Group	Cadaver No	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
A	1	38	32	84	72	106	104	46	38	38	32	46	38
A	2	36	30	88	68	102	100	48	44	36	34	48	44
A	3	34	36	82	66	108	106	50	46	40	36	50	46
A	4	40	28	84	70	110	102	46	40	32	32	44	44
A	5	32	26	80	74	104	100	52	48	34	34	46	42
A	6	42	34	78	68	108	104	54	54	38	34	48	44
A	7	36	36	86	74	98	98	48	46	38	32	48	48
A	8	40	26	88	66	104	100	50	48	36	34	44	40
B	1	52	46	96	88	118	112	56	52	48	42	54	48
B	2	54	52	100	96	110	102	54	48	44	38	50	50
B	3	50	48	96	96	106	100	60	58	42	38	52	46
B	4	56	48	98	94	112	112	62	56	46	40	54	48
B	5	52	46	100	94	108	106	58	50	44	36	56	48
B	6	48	44	106	98	116	110	60	52	46	40	48	42
B	7	54	52	104	98	108	100	64	60	40	36	56	48
B	8	52	50	104	100	110	104	62	54	38	34	54	50

Table 2: Legends for alphabets and figures used in Table 1

Group A	Cadavers embalmed by Formalin Solution (FS)
Group B	Cadavers embalmed by Saturated Salt Solution (SSS)
Cadaver number	Eight cadavers in Group A and eight in Group B. Numbered 1 to 8 in Each Group
V1	Flexion at shoulder joint (Rt)
V2	Flexion at shoulder joint (Lt)
V3	Abduction at shoulder joint (Rt)
V4	Abduction at shoulder joint (Lt)
V5	Flexion at elbow joint (Rt)
V6	Flexion at elbow joint (Lt)
V7	Flexion at hip joint (Rt)
V8	Flexion at hip joint (Lt)
V9	Abduction at hip joint (Rt)
V10	Abduction at hip joint (Lt)
V11	Flexion at knee joint (Rt)
V12	Flexion at knee joint (Lt)

Table 3: The mean, median and standard deviation of values V1 to V12

		V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
Mean		44.75	39.63	92.13	82.63	108.00	103.75	54.38	49.63	40.00	35.75	49.88	45.38
Median		45.00	40.00	92.00	81.00	108.00	103.00	54.00	49.00	39.00	35.00	49.00	46.00
Std Deviation		8.258	9.556	9.366	13.716	4.953	4.435	6.076	6.120	4.619	3.088	4.031	3.557
Percentiles	25	36.50	30.50	84.00	68.50	104.50	100.00	48.50	46.00	36.50	34.00	46.50	42.50
	50	45.00	40.00	92.00	81.00	108.00	103.00	54.00	49.00	39.00	35.00	49.00	46.00
	75	52.00	48.00	100.00	96.00	110.00	106.00	60.00	54.00	44.00	38.00	54.00	48.00

Table 4: The results of Mann Whitney *U* test. All variables (Range of Motion) have shown significant difference between Formalin Solution and Saturated Salt Solution – *p* - value is less than 0.05.

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12
Mann-Whitney U	0.000	0.000	0.000	0.000	8.500	17.000	.500	5.500	3.000	4.000	3.000	9.000
Wilcoxon W	36.000	36.000	36.000	36.000	44.500	53.000	36.500	41.500	39.000	40.000	39.000	45.000
Z	-3.378	-3.373	-3.373	-3.376	-2.498	-1.608	-3.323	-2.797	-3.077	-3.008	-3.087	-2.465
Asymp Sig (2-tailed)	.001	.001	.001	.001	.013	.108	.001	.005	.002	.003	.002	.014
Exact Sig [2 (1-tailed Sig)]	.000b	.000b	.000b	.000b	.010b	.130b	.000b	.003b	.001b	.002b	.001b	.015b

Not corrected for ties.

All variables have significant difference as shown in the tables

Discussion

Embalming has been practised since ancient times to preserve the dead bodies. The Egyptians were probably the first to do so, – the mummies preserved in the pyramids are most well-known example.

In the present study, it has been seen that cadavers preserved in SSS had attained high level of sterility. Two of the four cadavers did show bacterial growth, but that was restricted to single colony.

One of the earliest anatomists to use salt solution for preserving cadavers was Ambrois Pare (1510–1590).[1] The use of formalin solution is known since the times of Henry Gray. Formalin became popular because of its ability to cause instant coagulative necrosis and also its remarkable sterilizing powers. The fact that it causes shrinkage of tissues – esp loose connective tissue is not much of hindrance in anatomical study and dissection for teaching purpose, but it prevents effective utilization of cadavers for training in surgical techniques.[12]

For utilizing cadavers for surgical workshops, it is desirable that cadavers be preserved in a way that they resemble the living patient as far as possible. The high level of formalin which is used in the conventional embalming technique does preserve the cadaver and achieves high level of sterility. But it adversely affects the quality of cadaveric tissues

and organs, esp of soft tissue. This in turn affects joint flexibility.[2,13]

Besides hardening cadavers, formalin has other disadvantages: It dehydrates tissues, constricts arterioles and capillaries, rapidly coagulates blood and discolors skin through formalin pigment formation and gives unpleasant odour.[3,9]

In our study, SSS was not as effective as FS in sterilizing the cadavers. However, since only one colony each is grown from pharynx and peritoneal fluid in two cadavers, the risk of infection through SSS embalmed cadavers is negligible. Moreover, specialists and surgeons practicing surgical techniques do observe precautions like use of gloves and hand hygiene through 70% alcohol and washing of hands and arms before and after practice of surgical techniques.

The SSS has definitely proved superior to FS in other spheres of cadaver preservation. This includes range of motion of joints and pliability of tissues and skin. There is minimal hardening of tissues and organs. The offensive odor of formaldehyde is also absent. Though saturated salt exerts osmotic load, the dehydration so, typical of FS is absent.

Conclusion

Saturated salt solution offers a viable alternative to formalin solution for embalming cadavers for surgical workshops. The advantages include absence, of hardening and dehydration, increased range of motion of joints, greater pliability of tissues and skin and absence of strong odor.

Acknowledgements

The authors duly acknowledge the help received from Shri DR Basannar, MSc, MPS, Scientist F, Govt of India for statistical analysis for this research article.

Key Messages

Cadavers embalmed by saturated salt solution are better suited for surgical workshops than those embalmed by formalin solution.

Prior publication: Nil

Support: Nil

Conflicts of interest: Nil

Permissions: Nil

Total number of photographs: Nil

Presentation at a meeting: Nil

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