The utility of soft-preservation in Medical Education: Current trends & future directions

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SUMMARY

The future of Medical Education (ME) must be evaluated in light of the increasing variety and availability of educational models and embalming techniques for student and physician education and training. To evaluate the viability and sustainability of the different learning models, research and data on the diverse teaching modalities will be assessed from the perspectives of training residents and physicians. A literature review was conducted to provide an overview of the diversity of soft-preservation techniques presently available. It was shown that ME is optimized using soft-preservation techniques, but that many are limited in their present ability to accurately reflect the live human anatomy, and that more research must be done to identify the optimal preservation technique given unique educational needs. The aggregation of current research study results will aid educational programs in identifying the modalities of training most appropriate for their curriculum, and help in identifying models that can be utilized long-term to improve ME.

Key words: Medical Education – Simulation – Body donors – Soft preservation

INTRODUCTION

Medical Education

Medical Education (ME) can take on a variety of forms, depending upon the medical specialty. For practicing physicians, the scope of ME encompasses educational activities that aid medical professionals in maintaining, further developing, or increasing their professional and interpersonal knowledge and skills (AAMCE, 2022). While one's medical specialty may largely influence the specific set of Continuing Medical Education (CME) requirements, the overarching purpose is to aid physicians in continuing their life-long learning and to facilitate the enhancement of medical care to their patients and the medical field as a whole (University of Buffalo, 2018).

However, prior to being trusted with autonomy within the clinical setting, it is vital that physicians

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be well-practiced and competent in their skillset. While the process of medical training is long and arduous, in many ways a physician's technical proficiency is intimately linked with their amount of experience. Under ideal circumstances without real-world consequences, physicians would be able to practice on live patients. However, this is not feasible for legal and ethical reasons, as well as the premise of providing optimal care for patients. As such, identifying training methods that appropriately and accurately mirror live medical circumstances is vital for preparing physicians to practice autonomously. Such a model is referred to as simulation-based training (Al-Elq, 2010).

Simulation refers to artificially representing real world circumstances and settings. In the context of ME, simulation-based training involves the recreation of clinical scenarios to promote the acquisition of clinical skills through deliberate and repeated opportunities to practice, while also removing the direct consequences of practising on real patients under high-risk settings. Under simulated conditions, trainees and inexperienced medical professionals can learn without fear of harming their patients, focusing less on the consequences of their mistakes, but directing their attention primarily to the acquisition of skills and knowledge for future application (Al-Elq, 2010).

Forms of Simulation-Based Training

One of the primary modalities of simulation-based training involves the use of models. Simulation-based learning models can be categorized into several different classifications based on their resemblance to reality. Low-fidelity models include static models without realism or scenario-based context, while medium-fidelity educational tools have more resemblance to reality with basic life function characteristics (pulse, heart sounds, and breathing sounds), and high-fidelity simulators incorporate manikins that reproduce physical signs and physiological readings on monitors (Al-Elq, 2010).

More recently, virtual and augmented reality show promise in multiple realms of medicinal and surgical education. Neurosurgery is one of the medical fields that has benefited from integrating virtual reality into their training and practice. A study by Bernardo (2017) provided an overview of the current future utility of virtual reality simulators in neurosurgical training. By simulating three-dimensional scenes and evoking a comparable sensory experience similar to real life experiences, neurosurgeons were able to begin to learn complex tactile and often unnatural surgical skills/procedures through intuition, repetition, and direct computer/teacher feedback.

Another simulation model that has been utilized particular in surgical settings is the animal model. Being able to practice these skills and techniques in-vivo in the animal model facilitates procedural learning in a safe environment, sparing the negative consequences of practising on live patients (Bergmeister et al., 2020). However, while these simulation models can represent reality and can aid training physicians in the acquisition and practice of vital clinical and surgical skills, they cannot fully replicate it (Al-Elq, 2010). A study by Carey et al. (2014) highlighted that the primary limiting factor of simulation models is their lack of translatability to live conditions. They subsequently asserted that the next best option for simulating procedures was on human body donors due to its approximation of live tissue. Venne et al. (2020) similarly concluded that in addition to the initial expense of simulation models, the artificial modalities could not fully reflect the immense variability and intricacy of the live human anatomy. This is usually highlighted in the anatomical variations present in the human body along with the morbidity and causes of death that could only be appreciated when working with body donors (Konschake and Brenner, 2014; Balta et al., 2022). Therefore, the human body donor model remains in many ways the gold standard for ME and the acquisition of clinical and procedural knowledge. Human body donors have been used for anatomical education for centuries and their utility in clinical education has expanded over the years. For this reason, many of the studies investigating the use of body donors in clinical education would rely primarily on experiences in anatomical dissection (Balta et al., 2022).

Human Body Donor Model

Human body donors have been used in numerous medical fields to aid in procedural skills acquisition to overcome the initial learning curve, as well as to replace learning on live human patients (Porzionato et al., 2014; Yiasemidou et al., 2017; Watanabe et al., 2019; Nagase et al., 2022). One way in which human body donors have been utilized in internal medicine resident education is by simulating arthrocentesis (Gould et al., 2020). The study highlighted that, after the completion of a skills lab with human body donors, there was a 70% increase in confidence in performing arthrocentesis procedures. It was additionally noted that prior data and literature had shown that internal medicine program graduates had previously not felt adequately prepared to provide competent care to their patients in such procedures (Gould et al., 2020).

However, while studies have shown the potential of the human body donor model in ME, there is a significant constraint associated with the availability of unembalmed human body donors, limiting their viability as a continued and sustainable ME resource. While simulation would ideally be performed on unembalmed human body donors, the rate of decomposition of the human body makes this unsustainable for longitudinal ME. This rapid rate of decomposition has led programs to rely upon embalming techniques to prolong the viability and utility of each human body post-mortem.

Human Body Donor Embalming

While unembalmed human body donors initially reflect the color, texture, and tensile strength of unembalmed tissue, and seem like the obvious choice for simulating live operating conditions, their rapid decomposition following thawing presents many potential problems (Macchi et al., 2003; Hayashi et al., 2015). To avoid these issues, embalmed human bodies have been utilized to maintain desired anatomical properties, while minimizing the risk of infection and tissue desiccation as well as costs, and also maximizing body utility for teaching, educational, or surgical experiences (Hayashi et al., 2015).

Embalming is the process of exposing a subject to chemicals after death to prevent decay (Balta et al., 2015). Traditionally, chemical such as formaldehyde, glutaraldehyde, phenol, glycerin, bronopol, ethanol, and glycol have been utilized in embalming. However, each chemical and combination of chemicals offers unique benefits and drawbacks in quality of tissue, specifically in tissue appearance, texture, and flexibility. As such, it is vital that users assess each embalming method and identify the technique most optimal given their unique needs (Balta et al., 2018).

Types of Embalming Techniques

In discussing the utility of varying embalming techniques, it is important to define terms that have historically been ambiguously understood. When referring to a human body donor that has not been chemically treated, the appropriate term is an unembalmed human body donor. When an embalming solution produces a human body donor with joint flexibility less than that of the unembalmed body, the donor is described as "hard-fixed." In addition to hard-fixation, there is also an embalming technique known as "soft-preservation." Soft-preserved human body donors are defined as donors that have equal or more joint range of motion than that of the unembalmed human body donor (Balta et al., 2015).

Hard-fixation is the most common embalming technique, and it generally relies upon high concentrations of formaldehyde. Formaldehyde is one of the most common and important chemicals in embalming. Initially introduced in the late 19th century, it has been utilized consistently in human body donor embalming due to its low cost and wide availability. Working with formaldehyde is considered hazardous due to the carcinogenic impact on a living body and therefore strict exposure levels continue to be imposed (Balta et al., 2015). Human body donors embalmed with formaldehyde are often referred to as formalin-fixed. While formalin-fixation does offer excellent results in terms of eliminating potentially harmful bacteria, fungi, and other organisms, its high concentrations also result in extreme soft-tissue changes on the human body donor (Hayashi et al., 2015).

Formalin-fixed human body donors typically do not exhibit their normal tissue qualities, including color, texture, flexibility, elasticity, and pliability (Balta et al., 2015). The resultant tissues often take on a greyish hue, appearing noticeably different compared to their former state, and are pervaded by a pungent, potentially carcinogenic, and unpleasant odor (Balta et al., 2015; Hayashi et al., 2015). While this may be sufficient for learning basic human anatomy, surgeons have questioned how realistic embalmed human body donors are and have sought ways of better emulating live tissue. This concern has resulted in interest in soft-preservation techniques, including Thiel-preservation, Saturated Salt Solution (SSS), Imperial College of London – Soft Preservation (ICL-SP), N-vinyl-2-pyrrolidone, and Modified Larssen Solution (MLS) techniques, which purportedly better resemble live tissue (Balta et al., 2015).

SOFT-PRESERVATION

Soft-preservation was first pioneered by Walter Thiel in 1992 with the advent of Thiel- preservation to better preserve tissue characteristics, including color, texture, pliability, and structural integrity (Thiel, 1992a, 1992b). Another adaptation of the Thiel method was published in 2022 (Thiel, 2002). However, as new soft-preservation techniques had been developed and become more readily utilized the variety of different applications have also increased, particularly within ME (Balta et al., 2015).

Thiel-Preservation in ME

By a significant margin, the most heavily and diversely researched/utilized soft-preservative method is the Thiel-preservation technique which preserves a deceased human body for over a year as indicated in Table 1. With the solution being first implemented at the University of Graz, one of the first dealings was utilizing this technique as a learning and training model for arthroscopic surgery (Grechenig et al., 1999).

In the practice of thoracic endovascular aortic repair (TEVAR) and endovascular abdominal repair (EVAR), McLeod et al. (2017) simulated procedures utilizing Thiel-preserved human body donors in conjunction with extracorporeal pulsatile ante-grade flow into the aorta. It was concluded that, in conjunction with the perfusion of the aorta, Thiel-preserved human body donors appropriately simulated aortic endovascular procedures both anatomically and physiologically, and additionally had potential in interventional radiologic training and medical device testing (McLeod et al., 2017).

Thiel-preserved human body donors have also been assessed as a viable training model in the context of upper and lower urinary tract endoscopy training. Bele and Kelc (2016) determined that, while there were limitations to the model in comparison to performing the procedure on live patients, the model was suitable as a simulation model for the initial training of urethrocystoscopy and ureteroscopy. The primary drawbacks of the preservation technique were that the bladder mucosa lacked visible vessels, making the model unsuitable for clinically identifying mucosal abnormalities, as well as the lack of muscle tonus, which made ureteroscopy more difficult, although still possible (Bele and Kelc, 2016).

In the context of head and neck preservation, Miyake et al. (2020) sought to evaluate the Thiel-preservation method for head and brain surgery training. Thiel-preservation is known for being able to preserve tissue's natural color, flexibility, and plasticity, but generally causes brain softening, limiting Thiel-preservation in the context of intra-cranial procedure practice. However, when used in conjunction with intra-cerebral ventricular formalin injection, the brain yielded suitable elasticity for surgical simulation. The ability of the brain to be appropriately mobilized and to develop the needed surgical field suggested that the method could be used to improve head and brain human body donor surgical training (Miyake et al., 2020). Additionally, Humbert et al. (2022) utilized Hammer's modified Thiel technique to evaluate the preservation method in comparison to formalin-fixed and frozen heads. Assessing the models, surgeons ranked the modified Thiel-preservation technique the best for quality of dissection, tissue identification, submandibular and parotid gland dissections, and otologic surgery involving the skin/eardrum, bone and muscle tissue. The modified technique was only not preferred for endonasal dissection. These results showed that the use of modified preservation technique can improve the quality of head and neck surgical anatomy education similar to the findings of other studies (Feigl et al., 2007; Humbert et al., 2022).

In a study performed by Yiasemidou et al. (2017), researchers sought to evaluate Thiel-preserved human body donors as high-fidelity simulators over multiple surgical training specialties. It was determined that in examining the preserved donors over a broad range of specialties, anatomical accuracy and tissue properties were rated very positively, apart from preservation of the brain, eyes, and blood vessels (Yiasemidou et al., 2017). Several studies have also demonstrated the benefits of working with Thiel embalmed donors for ultrasound guided punctures and cricothyroidotomy (Benkhadra et al., 2008, 2009; Heymans et al., 2016).

In evaluating Thiel versus formalin-embalmed human body donors for thyroid surgery, Eisma et al. (2011) determined that the Thiel-preserved human body donors better represented real life surgical conditions. In assessing both the Thiel-preserved and formalin-embalmed human body donors, Thiel-preserved donors were preferred in all aspects including tissue quality (quality of skin, fat, muscle, blood vessels, and nerves), procedure perception (surgical position of the patient for the operation, designing the incision for the operation, making the incision, raising subplatysmal flaps, and retraction), and identification of structures (identification of muscular structures, vessels, the recurrent laryngeal nerve, and parathyroid glands) (Eisma et al., 2011).

In seeking to identify a suitable model for representing structures of the ear, Alberty et al. (2002) determined that Thiel-preservation effectively simulated temporal bone surgical training. Specifically in evaluating surgical techniques on external and middle ear structures, the structure and consistency of tissues of the auditory canal, tympanic cavity, and mastoid were regarded as comparable to live tissue, while the cartilage of the auricle was considerably softened (Alberty et al., 2002).

Additionally, Bailey et al. (2021) sought to improve ME through the utilization of Thiel-preserved human body donors. It was determined that the soft-preserved bodies were incredibly valuable for not only practising physical examinations and increasing participant confidence in performing Lachman tests, but also because live standardized patients (SPs) cannot reproduce physical examinations findings.

In a study performed by Hölzle et al. (2011), Thiel-preserved human body donors were evaluated in the context of dental education and for the teaching of oral surgery and implantology. Results indicated that even after weeks, the body maintained life-like tissue properties with the same high quality of tissue, particularly within the maxillary sinus membrane, mucosa, bone, and nerves, making the soft-preservation technique ideal for practising such oral procedures (Hölak et al., 2011).

In comparing fresh-frozen and Thiel-preserved human body donors for their suitability in biomedical education and research purposes, a study by Gatt et al. (2019) demonstrated there were no statistically significant differences identified between the two models regarding the kinematics and kinetics of the embalmed feet. It was concluded that such results indicated that the kinematic and kinetic properties of fresh-frozen and Thiel-preserved human body donor feet were not dissimilar, suggesting that they could be interchangeable in ME and research (Gatt et al., 2019).

In assessing Thiel-preserved human body donors in tropical weather, Reddy et al. (2017) sought to modify and improve the utility of the soft-preserved bodies in non-temperate climates. Generally, while Thiel-preserved human body donors have been accepted and effectively used in temperate climates, their use in tropical locations has been limited due to the poor short-term preservation outcomes. However, utilizing a modified Thiel-preservation technique, the soft-preserved bodies were successfully used for various surgical simulation exercises, making the use of Thiel-preserved human bodies more accessible and sustainable in tropical countries and locations (Reddy et al., 2017).

Thiel-preservation has also been evaluated in veterinary anatomy education. In a study conducted by Nam et al. (2020), while Thiel-preserved tissues were the most expensive embalming method, they also were superior to formalin-fixed bodies for joint and muscle movement, lack of offensive/irritating odor, preference by students for identifying anatomical structures, and maintaining muscle and internal organ color and texture comparable to living animals.

Thiel-preserved human body donors have been also evaluated for their viability in laparoscopic, endoscopic, and microsurgical procedures. Porzionato et al. (2014) identified Thiel embalmed human body donors as being viable learning models for teaching transanal/transrectal and transvaginal Natural Orifice Transluminal Endoscopic Surgery (NOTES). Additionally, Rashidian et al. (2019) found that for training laparoscopic liver surgery the Thiel-preserved human body donors were considered to be superior to other training modalities, including proctoring in the operating room, virtual reality, video training, and practice on pigs. A study by Ruiz-Tovar et al. (2019) determined that Thiel-preserved human body donors were the optimal method for the simulation of laparoscopic bariatric surgery over other teaching modalities, including virtual reality simulators and practice on animal models, owing to the body's ability to simulate life-like elasticity of the tissues necessary for laparoscopic bariatric surgery simulation. For evaluating Thiel-preserved human body donors in laparoscopic Roux-en-Y gastric bypass procedures, Zevin et al. (2012) concluded that the model was superior to both the porcine model and virtual reality simulation by offering tactile practice, preserving tissue color and consistency comparable to real life, and allowing participants to practise patient positioning. And in a study performed by Odobescu et al. (2019), Thiel-preserved human body donors were regarded positively as high-fidelity simulation models for training surgeons the basics of nerve repair, preserving the fascicles, perineural, and epineural sheaths well.

While the soft-preservation of human body donors has been studied most utilizing the Thiel-preservation technique, in seeking to further improve ME and surgical skills training different soft-preservation techniques have been invented and studied, including the Saturated Salt Solution (SSS).

Saturated Salt Solution in ME

In seeking to identify an ideal human body donor embalming/preservation technique for surgical skills training, Hayashi et al. (2014) compared formalin-fixed, Thiel-preserved, and SSS methods based on bacterial/fungal cultures and range of motion measurements (Hayashi et al., 2014). Results from the study indicated that the

Table 1. Advantages and disadvantages of soft-preservation techniques.

Soft Preservation Techniques			
Techniques	**Advantages**	**Disadvantages**	**Investigated Specialty**
Thiel	- Long term preservation - Thoroughly investigated	- Expensive - Immersion needed - low levels of formaldehyde	Pediatrics [21], TEVAR [22], Endoscopy [23], Brain Surgery [24], Temporal Bone [28], Oral Surgery [30], Liver surgery [35], Bariatric surgery [37]
Saturated Salt	- Long term preservation	- Expensive - Immersion needed - Corrosive material - Formaldehyde & phenol present	Orthopedics [40], Oral Procedures [41], Trauma Surgery [44]
ICL- SP	- Inexpensive - No immersion needed	- Short term preservation - Understudied - Formaldehyde & phenol present	Surgical Skills [11], Gynecology [44]
N-Vinyl-2-Pyrrolidone	- Inexpensive - No immersion needed - Long term preservation - No formaldehyde & phenol	- Understudied	Laparoscopic Training [45]
Modified Larssen	- Inexpensive - No immersion needed	- Formaldehyde present - Short term preservation	Surgical Training [46]

SSS method sufficiently neutralized infectious agents, produced bodies with flexible joints and high-quality tissue for surgical skills training that remained in good condition for a long period of time as outlined in Table 1. This method also produced tissues acceptable for ultrasound imaging, central venous catheterization, and incision with cauterization and auto suture stapling (Odobescu et al, 2019).

In the context of orthopedics specifically, Burns et al. (2018) sought to further evaluate SSS in the improvement of surgical skills training. Comparing SSS-preserved human body donors to those embalmed with formaldehyde or alcohol-glycol solution, the SSS bodies were regarded as superior to the bodies embalmed in other methods, producing joints with suitable motion, stiffness, visual and tactile tissue fidelity, and odor suitable for high-fidelity surgical skills training.

In the training of oral surgical skills, Watanabe et al. (2019) determined that, after completion of six procedures associated with intra- and extra-oral bone harvesting with SSS-preserved bodies, self-assessed confidence levels showed statistically significant increases. Additionally, in examining the anatomical features of the SSS-preserved human body donors, the oral mucosa and skin were regarded as similar to living tissues with bone tissue hardness and realism being maintained, and all procedures offering sufficient realism at lower preparation and storage cost, with minimal odor (Watanabe et al., 2019).

Evaluating SSS-preserved human body donors for the surgical simulation of trauma surgeries, Homma et al. (2019) concluded that SSS-preserved bodies are useful for surgical skills training, especially surgical repairs. Results specifically indicated that SSS bodies were more suitable than formalin-fixed bodies for surgical skills training and that participants in the study showed increased self-assessed confidence after completion of the trauma surgery seminar after half a year, with the exception of external fixation for pelvic fracture (Homma et al., 2019).

In a study by Nam et al. (2020), authors evaluated SSS-preserved, Thiel-preserved and formalin-fixed tissues. Tissues preserved by SSS were more expensive than formalin-fixation and less expensive than Thiel-preservation, but, like the Thiel-preserved tissues, the SSS-tissues facilitated superior joint and muscle movement in comparison to formalin-fixed tissues, preserving lifelike muscle and internal organ color and texture, with no offensive smell, and being preferred by students for identification of anatomical structures (Nam et al., 2020).

Soft-preservatives have also expanded into phenol-based solutions including the Imperial College of London – Soft-Preservation (ICL-SP) technique.

Imperial College of London – Soft-Preservation in ME

A limited number of studies have investigated the ICL-SP technique compared to the Thiel and SSS embalming techniques. A study by Venne et al. (2020) compared Thiel-preservation to phenol-based preservatives such as the ICL-SP technique. This study concluded that donors embalmed using a phenol-based technique had similar features to that of Thiel embalmed donors. Results of the study indicated that all participants rated the phenol-based tissues consistently better or equivalent to the Thiel-preserved tissues for surgical skills training, there was no statistically significant difference in tensile elasticity between ICL-SP tissue and fresh tissue, and the phenol-based technique better preserved skin histologically (Venne et al., 2020).

In a study directly investigating the utility ICL-SP donors in the training of gynecological oncologists, Barton et al. (2009) concluded that soft-preserved bodies should be used over formalin-fixed in surgical training. It was noted that while the trainees' anatomical knowledge was initially weak, as the surgical skills lab progressed through surgical dissection of the abdomen and pelvis, subspecialty participant knowledge improved markedly, represented by pre- and post-skills lab evaluations (Barton et al., 2009).

Another soft-preservation technique developed in order to circumvent the health hazards and overhardening associated with formalin-based solutions is N-vinyl-2-pyrrolidone.

N-Vinyl-2-Pyrrolidone in ME

In a study performed by Nagase et al. (2022), it was determined that donors preserved using N-vinyl-2-pyrrolidone had soft and pliable tissue that lasted up to thirty-seven months without any change in the quality of tissue. In the review, they also introduced the preservation technique in surgical and medical procedural training, including endotracheal intubation, motion physiology of the vocal folds, laparoscopic and endoscopic procedures, and the development of medical devices (Nagase et al., 2022).

An embalming technique that also sought to mitigate the disturbing smell, mucosal irritation, discoloration, and rigidity associated with formalin-fixation was the modified Larssen solution.

Modified Larssen Solution in ME

In seeking to identify an appropriate and affordable embalming technique that preserved tissue color, texture, pliability, and flexibility for numerous repeated surgical trainings, Bilge and Celik (2017) concluded that Modified Larssen Solution (MLS) effectively served as a sustainable and cost-effective embalming method for surgical training. Results indicated that skin color did not change after MLS perfusion, and that the color of muscles, fasciae, fatty tissue, nerves, and vessels were determined to be life-like for both open and laparoscopic procedures. Additionally, MSL-preserved bodies had no irritating odor, exemplified elbow flexion comparable to fresh-frozen human body donors, and the tissue properties mimicked life-like tissues for several weeks without changing (Bilge and Celik, 2017).

Finally, a study performed by Balta et al. (2018) sought to compare the effects of embalming fluids on the structures and properties of tissues in human body donors. The quality of tissue did not change in an ICL-SP embalmed donor for 4-6 months. When comparing formalin, genelyn, Thiel and ICL-SP techniques, the results showed that formalin and genelyn solutions decreased joint mobility and Thiel technique increased mobility. Genelyn is a commercially available solution that does contain formaldehyde (Balta et al. 2015). ICL-SP joints demonstrated similar range of motion to their unembalmed measurements, indicating that ICL-SP faithfully mimics the joints of unembalmed bodies and would be ideal for the simulation of orthopedic and rheumatologic training. The study also sought to evaluate the effect of embalming solutions on internal organs and vessels. Results indicated that formalin-based solutions better maintained the shape of the organs and vessels investigated than did Thiel-preserved. It was noted that formalin is necessary in order to retain the size and shape of organs and vessels under study owing to the formaldehyde's fixing abilities, while solutions without strong fixing agents result in collapsing tissues (Balta et el., 2018).

CURRENT UTILITY AND FUTURE OF SOFT-PRESERVATION IN MEDICAL EDUCATION

Within the context of reduced work hours and an increased scrutiny of patient safety, there is an unmet need for more realistic and cost-effective training tools in ME. These modern constraints have led to an increased reliance on simulation to provide opportunities for simple and complex skill acquisition outside of clinical practice. Simulation in ME decreases stress, increases confidence, and allows for a mitigation of the learning curve for the medical trainee, particularly for procedural-based skills. While formaldehyde-fixed human body donors allow for accurate identification of relevant anatomy, soft-preserved models provide an invaluable experience for learners as cost-effective realistic simulation.

As evidenced in the studies previously cited, soft-preserved human body donors provide a more realistic model that has been proven effective in ME and training across specialties. As the models can be utilized for several months, a single donor can be efficiently utilized for numerous different procedure-specific or anatomic-based labs. Future studies should focus on comparative effective analyses of soft-preserved models compared to other high-fidelity models and the integration of additional techniques to better simulate a real patient experience (i.e., perfused models). It would be also important to perform an in-depth critical analysis of the benefits of human body donor simulation through an assessment of students' skill development (objective measures of skill development/acquisition) and how these may potentially translate to improved patient outcomes.

CONCLUSION

Increasingly in the 21st century, there is a myriad of different simulation methods, embalming techniques, and innovations in technology that have benefit in ME. While many of them show immense promise and future potential, most have distinct drawbacks and are still in the infancy of their implementation, and/or are lacking in some capacity, being unable to wholly simulate and represent the immense variability of the live human. In seeking to emulate the unembalmed human body as accurately as possible, embalming and preservation techniques have evolved in order to circumvent and overcome the distinct drawback of traditional formalin-embalming techniques.

The purpose of this review was to provide an overview of the diversity of soft-preservation techniques presently available. Only once more research is performed on less readily known preservation techniques such as SSS, ICL-SP, N-Vinyl-2-pyrrolidone, and MLS, and direct comparison is performed against Thiel-preservation and fresh-frozen human body donors, can an optimal embalming solution be identified for future ME practices. However, as of now it is vital that users assess each embalming method and identify which techniques are optimal given their unique educational needs.

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