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My Thoughts / My Surgical Pratice

Thiel embalmed human cadavers in surgical education: Optimizing realism and long-term application☆

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Within the various types of surgical training models, human cadavers are unique as they provide unparalleled anatomical details and advanced training opportunities. Traditionally, formalin-based methods were used for medical education, but these tend to render the tissues hard, discolored, and less elastic, impeding surgical training. More importantly, formaldehyde is a hazardous indoor pollutant and it has been recognized by the International Agency for Research on Cancer (IARC) as carcinogenic.[1,2] While traditional preservation methods generally contain between 4% and 8% formaldehyde, this concentration is reduced to 0.8% in Thiel bodies. The original Thiel embalming technique uses a highly specific sequence, quality and quantity of fluid injections over the course of three days followed by prolonged submersion in an embalming bath to attain a more realistic preservation.[3] This soft embalming method ensures that preserved tissues retain their natural color and consistency. However, this technique is mainly used in German-speaking countries. In 2011, a global survey on its use among 311 anatomy laboratories and institutes stated that only 56% of responding centers know this method, of which only 10% regularly employ it.[4] Despite the relative unawareness of the Thiel embalming technique, these cadavers create valuable opportunities for surgical training by enhancing realism.

To review applications of Thiel embalmed human cadavers in surgical education, an electronic systematic literature review was conducted using MEDLINE, Embase, CENTRAL, and Web of Science databases from inception to November 2019 conforming to the PRISMA guidelines. Studies describing applications of Thiel cadavers in surgical education were included. Methodological quality was appraised using NOS-E (Newcastle-Ottawa Scale for Education), and the impact of educational interventions were assessed based on Kirkpatrick's four-level model.

Of the 1,159 screened abstracts, 32 full-text articles were eligible for inclusion (Fig. 1). Thiel cadavers have been utilized for training in the following surgical specialties: plastic surgery ($n = 6$), urology ($n = 4$), cardiac surgery ($n = 3$), gastrointestinal surgery ($n = 3$), emergency medicine ($n = 2$), orthopedics ($n = 2$), vascular surgery ($n = 1$), gynecology ($n = 1$), ENT surgery ($n = 1$), endocrine ($n = 1$), transplantation ($n = 1$), oral surgery ($n = 1$), and combinations of multiple surgical specialties ($n = 6$). Sixteen studies were purely descriptive, whereas outcome assessment was performed in 16 articles. Of these, 13 evaluated the impact of the training intervention using subjective measures, and three studies assessed training impact by changes in learner knowledge or improvement in psychomotor skills, corresponding to the Kirkpatrick's score of two (Supplementary material Tables 1–3). Rai et al. have proven the face and construct validity of Thiel-embalmed cadavers as a learning tool for training in laparoscopic nephrectomy.[5] Also, a significant improvement in surgical performance was seen in the cadaveric ontological training set-up by Feigl et al.[6] The study of Böckers et al. could not show an objective increase in examination performance (change in knowledge), although increased learning motivation of participants was reported.[7] Except for one article, all studies were deemed weak in methodology (NOS-E < 4). The study of Rai et al. got 4 out of the maximum of 6 score; rigorous reporting of the representing groups, the controlled characteristic by which two comparison groups were established, and plausible bias introduction aided the study to attain this score.[5]

In general, the excellent simulation of live patients in Thiel cadaveric workshops is the overpowering advantage acknowledged by almost all studies. Depending on the surgical specialty, this is reflected in various aspects. For example, plastic surgeons and urologists repeatedly confirm the high quality and well-preserved soft tissues. The ability to establish a pneumoperitoneum, a pneumothorax or a pneumomediastinum due to retained tissue suppleness falls under the same category. Owing to the Thiel cadavers' soft preservation and flexibility, displacement of intra-abdominal organs during lung ventilation has been described as advantageous for minimally invasive surgery training.[8] From an orthopedic standpoint, accurate range of motion and joint flexibility is applauded. Together with the often mentioned odorless, yet, disinfecting properties without harmful substances, the excellently preserved tissues and lifelikeness give Thiel embalming a significant benefit over traditional formalin-based preservation methods. Thiel cadavers accurately represent the scope of human anatomical and physiological variability (including atherosclerosis), which animal models evidently cannot. Subsequently, this may lead to reduction in animal cadaver use. Further advantages were noted, including the possibility for long-term, sustainable usage owing to excellent cadaveric preservation, versatility in surgical applications, realistic

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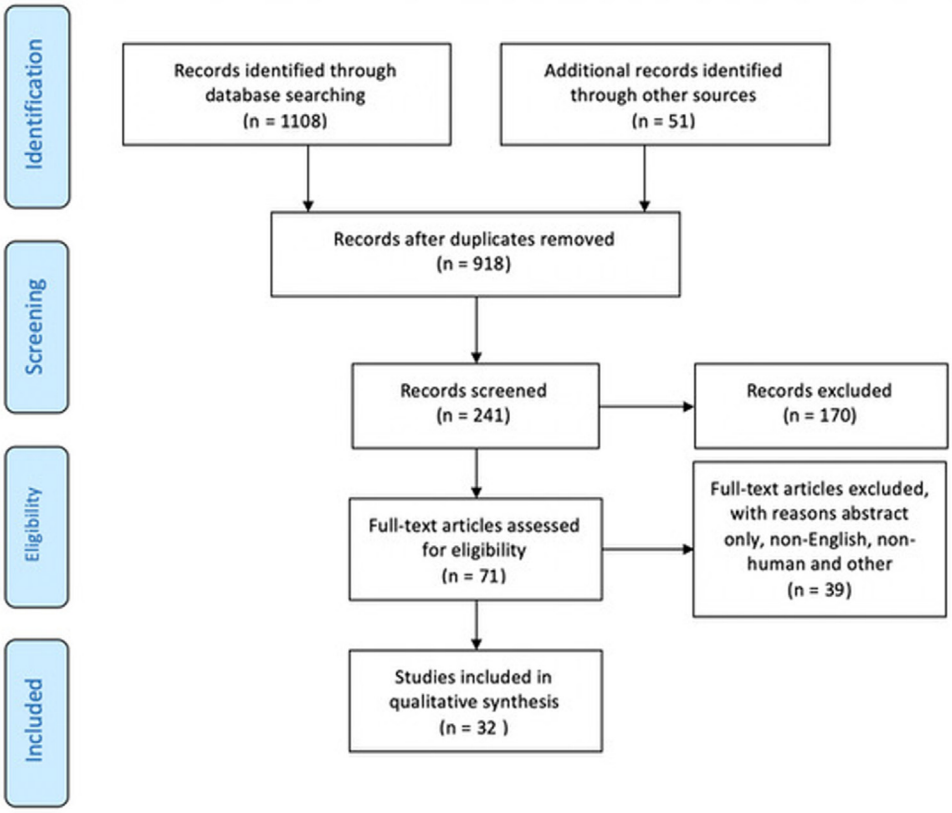

Fig. 1. PRISMA flow diagram.

ultrasound echogenicity, and the ability to replace blood with saline for valve visualization in cardiac surgery training.

Nonetheless, Thiel cadavers also face a few drawbacks. The most commonly named is its high cost. Authors reckon 1,000 USD per specimen to do the complex and time-consuming body preparation, stressing maximal usage of cadavers.[9] For single-use training workshops, the high cost can be off-putting. This may be offset (and even come out positively) with long-term usage in a broad range of versatile surgical applications. Secondly, thirteen articles mentioned vascular problems. A lack of pulsatile flow impedes a broad range of interventions in endovascular courses, evaluation of flap survival and thrombosis rate in plastic surgery and general assessment of tissue perfusion and venous return. Five studies mitigated this problem by creating artificial circulation, yet, this too posed limitations such as lower achieved vascular pressures or altered properties of circulating fluid (e.g. saline) when compared to blood. Moreover, the model receives a broad scope of critique inherent to the inanimate model: lack of muscle tonus, lack of myocardial contractions, and absence of bleeding or peristalsis. Hence, animal models strongly compete with Thiel cadavers on a cardiovascular basis. While brains of these cadavers have been reported to be in an excellent anatomical condition up to 15 months after embalming in one study, three studies have described an inferior quality of nervous tissue, specifically that of the brain, eyes and smaller peripheral nerves. Older Thiel cadavers were also noted to suffer from substantial fluid loss, impeding ultrasound imaging or interventions concerning cerebral ventricles.

Considering the flexible tissue properties, superior color preservation, and lack of hazardous fumes, Thiel bodies are a significant improvement compared to formalin-based preservation. Thiel bodies are beneficial to practice various surgeries and the higher cost can be offset by the possible long-term use. Continued research into new applications and training courses on Thiel cadavers is highly recommended and would be a beneficial step to broadly introduce its anatomical and surgical training values. Future studies should focus on the effectiveness of this training tool on learner behavior and patient outcomes.

Appendix A. Supplementary data

Supplementary data to this article can be found online at.https://doi.org/10.1016/j.amjsurg.2020.10.007

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