Journal of Forensic Radiology and Imaging xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Forensic Radiology and Imaging

journal homepage: www.elsevier.com/locate/jofri

Assessing radiological images of human cadavers: Is there an effect of different embalming solutions?

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ARTICLE INFO

Keywords:
CT
Radiographs
Ultrasound
Cadaver
Embalming
Anatomy

ABSTRACT

Objectives: The aim of this study is to investigate the impact of different embalming solutions including formalin, Genelyn, Thiel and Imperial College London- Soft Preserving solutions on the quality of radiological images taken from cadavers embalmed with the above mentioned techniques.

Materials and methods: Two cadavers per embalming technique were imaged pre and post-embalming using three different imaging modalities including ultrasound, plain radiography and computed tomography (CT). Imaging criteria and a qualitative grading system for each imaging modality were adapted from the European Guidelines on Quality Criteria for Computed Tomography, the European Guidelines on Quality Criteria for Diagnostic Radiographic Images, and according to the AIUM Practice Guideline for the performance of ultrasound. Qualitative analysis was performed independently by three readers on a Picture Archiving and Communication System (PACS). The readers were blinded to both the embalmment status and the embalming agent used to preclude bias.

Results: On comparison of images pre and post-embalming, brain CT images showed a significant deterioration in image quality post-embalming, while there was no significant change in chest and abdomen/pelvic images and some improvement was observed in Genelyn embalmed cadavers. No changes were observed when using ultrasound to image the spleen and aorta, while a significant improvement in image quality was observed when examining the kidney in all embalmed cadavers with a small improvement when imaging the liver. No significant difference was observed on plain radiography post-embalming, while a minor deterioration was observed mainly in the chest area.

Conclusion: Different embalming techniques had varying effects on image quality, in human cadavers, with the range of imaging modalities investigated in this study. Thus, no ideal embalming solution was identified, which would improve the quality of images on all imaging modalities. Further research is required to compare the quality of radiological images at different stages of decomposition taking into consideration antemortal pathologies with a larger number of donors.

1. Introduction

Human cadavers are used in different disciplines for teaching, research and training. The dissection of the human cadaver has been considered a superior tool to teach anatomy by both anatomists and students [1,26]. In the early 1990s, medical curricula internationally started to change from a subject based approach to a multi-subject integrated system [2]. Though integrating anatomy with other clinical sciences was recommended only 20 years ago, the use of radiological imaging to supplement the teaching of human anatomy was first reported over 50 years ago [3]. Several studies have reported the advantages of using radiological images when teaching human anatomy [4,5]. Some of these advantages include the use of radiological images to understand the three-dimensional aspect of anatomical structures and their complex positions [4]. Retention of the anatomical knowledge learnt in the first 2 years of the medical curriculum has always been a challenge. Studies have shown that the use of radiological images in cadaver dissection improves the students' ability to retain the ability to identify structures on plain radiography in the long and short-term [3]. This integration does not only help in improving anatomical education, but is crucial in enhancing the students' ability to understand diagnostic radiology later in their undergraduate and post-graduate careers [6].

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http://dx.doi.org/10.1016/j.jofri.2017.08.005
Received 5 June 2017; Accepted 1 August 2017

From a clinical perspective, the use of cadavers to educate and train clinicians and postgraduate medical students using radiological imaging has been reported in the literature [7,8]. Cadaver based ultrasound-guided regional anaesthesia training is widely employed [8–11]. Furthermore, the use of human cadavers in vascular sonography training and also for practicing common interventional clinical skill, such as femoral central venous access has proven invaluable [12].

Diverse radiological modalities (Computed tomography, magnetic resonance images and ultrasound) are also increasingly utilized in forensic medicine and pathology [13]. The use of plain radiography and CT supplements the information gained from conventional post-mortem. The number of articles published in the field of post-mortem and forensic radiology has increased from a dozen in 2000 to a dozen per month in 2011 [14]. The reason could be due to the fact that interpreting post mortem images is frequently different to in-vivo imaging, thus a new radiological post mortem sub-specialty has emerged. Though post-mortem imaging has increased exponentially, technical difficulties including lack of contrast enhancement, post mortem decomposition and difficulties with differencing “normal” post-mortem imaging findings from findings related to pre-mortem illnesses remains challenging [15]. There is also increasing interest in combining anatomic dissection in human cadavers, with imaging (e.g. CT) of these cadavers following donation, to enhance student experience. These reasons motivated this study, in which, we aimed to investigate the influence of different chemicals and embalming techniques on the quality of radiological images obtained from human cadavers.

Embalming is the process of introducing chemicals into a human cadaver to arrest decomposition of tissue while reducing health hazards [16]. This practice is common when using cadavers to deliver dissection-based anatomy teaching programs. Formaldehyde has traditionally been used to preserve the human body, but as it affects the quality of tissue, research has now focused on developing new embalming techniques and solutions to preserve a tissue compliance that is more comparable to the living human body [16,27]. Some of these techniques including Thiel [17], Genelyn [18], and Imperial College London-Soft Preserving solution have been compared in a study of the use of cadavers in the training of gynaecological oncologists [19]. Negative effects of embalming on the quality of radiological imaging have been reported previously [4,6]. The use of Formaldehyde/phenol in an embalming solution was considered to be the primary reason for the decrease in the quality of images as they induce soft tissue oedema [20]. Recent studies have reported the advantages of embalming a human cadaver using a soft tissue preserving technique, such as Thiel, as it results in improved quality of radiological images [9].

To the best of our knowledge, this is the first study comparing the impact of different embalming techniques (formalin, Thiel, Genelyn, and London) on image quality in human cadavers on several imaging techniques routinely used in clinical practice including ultrasound, radiography and computed tomography The first study to investigate different imaging techniques on embalmed cadavers was in 2013 where only one embalming technique was assessed [21]. A further study in 2014 compared different embalming techniques using ultrasonography [22]. The aim of this study is to compare the quality of radiological images in human cadavers before and after embalming with different embalming techniques.

2. Materials and methods

The study was carried out under the auspices of the ‘License to Practise Anatomy’ granted by the Irish Medical Council to the Chair of Anatomy under the Anatomy Act 1832. For the purpose of the study 8 human cadavers were embalmed using four different embalming techniques. Donors premorbidly signed written consent for the use of their bodies by the department of Anatomy and Neuroscience for education and research. Appendix A includes details on the different embalming solutions.

Cadavers were imaged pre and post-embalming using three different imaging modalities including ultrasound, radiography and CT. Imaging criteria and a qualitative grading system for each imaging modality were adapted from the European Guidelines on Quality Criteria for Computed Tomography [23], the European Guidelines on Quality Criteria for Diagnostic Radiographic Images [24], and according to the AIUM Practice Guideline for the performance of ultrasound [25]. Qualitative analysis was performed independently by three readers (MT, FM, and OJOC) on a Picture Archiving and Communication System (PACS) (Impax 6.3.1; Agfa Healthcare, Mortsel, Belgium). The readers were blinded to both the embalmment status and the embalming agent used to preclude bias.

2.1. Computed tomography

Whole body multi-detector scanning including the brain, thorax, abdomen and pelvis was performed pre and post-embalming by two specialist CT radiographers using a 128-slice Discovery HD 750 (GE Healthcare GE Medical systems, Milwaukee WI, USA). The cadavers were scanned supine, cranio-caudally, with their arms by their sides. The following CT parameters were used in conjunction with automatic exposure control: tube voltage: 120kVp; gantry rotation time: .8 s; collimation: 40 × .62 mm; and pitch factor: .98. Images were reconstructed from an acquisition thickness of .625 mm to a final slice thickness of 1.25 mm. All images were reconstructed from the raw-data acquisitions using the standard departmental protocol employing hybrid iterative reconstruction (60% filtered back projection and 40% ASiR, adaptive statistical iterative reconstruction) (GE Healthcare, GE Medical Systems, Milwaukee, USA).

Three readers qualitatively rated different structures in 3 anatomical regions according to a four-point scale: 1 = not visible, 2 = poorly visible, 3 = adequately reproduced, 4 = very well reproduced in comparison to images from patients. The results were summated per body part to give a total raw score. A calculated score to facilitate comparisons was derived by dividing the total raw score by the number of criteria assessed.

In the brain, radiologists rated the visibility of the skull, grey-white matter differentiation and the ventricular system. In the chest, the visibility of the thoracic wall, lung parenchyma, heart, aorta, superior vena cava and vertebrae were rated. In the abdomino-pelvic area, the aorta, inferior vena cava, liver, kidneys, spleen, pancreas, intraperitoneal fat, vertebrae and pelvis were rated.

2.2. Ultrasound

Ultrasound of the solid abdominal viscera including the kidneys, liver, aorta, and spleen was performed using an Ultrasonix L14-5/38GPS by a single radiologist (MT). Representative images were recorded and reviewed by the other two radiologists and a final score was allocated in consensus. The visibility of the following solid viscera and vascular structures was rated: kidney: long axis (both poles visible), transverse length, renal cortex and renal pelvis; liver: left lobe, right lobe, common bile duct, and portal vein; spleen: long axis (both poles visible), transverse length; aorta: anterior and posterior abdominal wall visibility in the transverse plane and anterior and posterior visibility in the longitudinal plane.

Percutaneous biopsy of the liver was performed with an 18 G automated core biopsy device by a single radiologist (MT) (Co-axial Temno biopsy device, Carefusion Corporation, San Diego CA, USA). Needle visibility was assessed on a three-point scale: 0 = not visible, 1 = poor visibility, 2 = good visibility.

2.3. Plain radiography

Plain Radiography was performed by an experienced radiographer using an Axiom Aristos digital radiography unit (Siemens Healthcare