



Contrast-enhanced cadaver-specific computed tomography in gross anatomy teaching

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Abstract

Objectives To establish contrast-enhanced (CE) cadaver-specific post-mortem computed tomography (PMCT) in first-year gross anatomy teaching and quantitatively evaluate its learning benefit.

Methods 132 first-year medical students were included in this IRB-approved study and randomly assigned to an intervention group (n=59) provided with continuous access to CE and non-enhanced (NE) cadaver-specific PMCT-scans during the first-semester gross anatomy course, and a control group (n=73) that had only NE cadaver-specific PMCT data available. Four multiple-choice tests were carried out (15 questions each) subsequent to completion of the corresponding anatomy module: Head and neck anatomy, extremities, thorax, and abdomen. Median test results were compared in each module between the groups using the Wilcoxon rank-sum test. Additionally, participants of the intervention group answered a 15-item feedback-questionnaire.

Results The intervention group achieved significantly higher test scores in head and neck anatomy (median=12.0, IQR=10.0–13.0) versus the control group (median=10.5, IQR=9.0–12.0) ($p<0.01$). There were no significant differences in the comparison of other modules. CEPMCT was highly appreciated by undergraduate medical students.

Conclusions The incorporation of contrast-enhanced cadaver-specific PMCT-scans in gross anatomy teaching was proven to be feasible in the framework of the medical curriculum and significantly improved the students' learning performance in head and neck anatomy.

Key Points

- *Cadaver-specific contrast-enhanced post-mortem CT (CEPMCT) is feasible in the medical curriculum.*
- *CEPMCT yields significantly improved learning performance in head and neck anatomy ($p<0.01$).*
- *CEPMCT is highly appreciated by medical students and used in tutor- or self-guided modes.*

Keywords Medical education · Computed tomography angiography · Anatomy · Anatomy, cross-sectional · Post-mortem examination

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Abbreviations

CE	Contrast-Enhanced
CEPMCT	Contrast-Enhanced Post-mortem Computed Tomography
CG	Control Group
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
IG	Intervention Group
IRB	Institutional Review Board
IQR	Interquartile Range
MC	Multiple Choice

MRI	Magnetic Resonance Imaging
NE	Non-Enhanced
NEPMCT	Non-Enhanced Post-Mortem Computed Tomography
OA	Overall Agreement
PMCT	Post-Mortem Computed Tomography
SSD	Opaque Shaded Surface Display

Introduction

Human gross anatomy is a fundamental part of medical education and forms the basis of correct radiological image interpretation. The use of cadaver-specific post-mortem radiography in the teaching of gross anatomy was reported for the first time by Mc Niesh et al. in the 1980s [1]. In today's medical curricula, several universities use cadaver-specific post-mortem computed tomography (PMCT) scans in preclinical gross anatomy teaching [2–7]. A majority of the performed studies investigating this teaching method revealed a learning benefit, both qualitatively [3, 7] and quantitatively [4, 6]. The particular strength of this approach is the close interlinking of manual dissection and virtual anatomy by means of PMCT scans visualized on CT workstations in the gross anatomy laboratory.

Until today, only non-enhanced cadaver-specific PMCT (NEPMCT) has been incorporated in medical curricula. However, NEPMCT lack specificity regarding attenuation of different tissues or visualization of the vascular system in the same way as clinical non-enhanced CT scans do [8]. In the field of forensic medicine, researchers of the Virtopsy® project (Institute of Legal Medicine, Bern, Switzerland) demonstrated the feasibility of whole-body contrast-enhanced PMCT (CEPMCT) with separate visualization of the arterial and venous system employing a modified heart-lung machine as a perfusion device [9–11]. First applications of CEPMCT in clinical and preclinical teaching modules were recently reported by Riederer et al. [12].

We hypothesized that a full implementation of whole-body cadaver-specific CEPMCT is feasible in a gross anatomy laboratory and yields improved learning performance. Therefore, the purpose of this study was to establish cadaver-specific CEPMCT in the preclinical medical curriculum and to quantitatively investigate its learning benefits.

Materials and methods

This prospective randomized controlled study received IRB approval and was carried out between September 2016 and February 2017. Written informed consent was obtained from all participants.

Curriculum design

In October 2013, the anatomical curriculum at Heidelberg University was extended by non-enhanced cadaver-specific PMCT scans and virtual dissection modules while maintaining physical dissection as central teaching element. The total course time consists of 191.5 contact hours, with 94.5 h allocated to lecture time, 78 h allocated to physical dissection (each appointment with continuous access to cadaver-specific PMCT data on workstations installed next to the dissection tables) and 19 h allocated to radiological image interpretation training in tutor-guided seminars and teaching sessions at life-size virtual dissection tables (Anatomege Table, Anatomage Inc., San Jose, CA, USA) [4]. The new elements of the anatomical curriculum were previously reported in detail by Paech et al. [4].

Contrast-enhanced post-mortem computed tomography (CEPMCT)

In 2014, our institution started to perform contrast-enhanced PMCT scans. All PMCT scans were acquired on an institution-owned 16-line CT scanner (Toshiba Aquilion 16) with the following scan parameters: Head/Neck (120 kV, 170 mAs, 0.5 mm slice thickness, increment 0.1 mm, kernel sharp, window brain) and Thorax/Abdomen/Lower Limb (135 kV, 75 mAs, 1.0 mm slice thickness, increment 0.5 mm, kernel sharp, window abdomen). The applied contrast agent Angiofil® (Fumedica AG, Muri, Switzerland) consists of iodized linseed oil and was developed especially for post-mortem usage [8]. The used protocol was derived from the publication by Grabherr et al. [8]: 220 ml of contrast agent were mixed with 3.5 L of paraffin oil and injected into the femoral artery (1,200 ml) and subsequently into the femoral vein (1,800 ml) using a pneumatically-driven pump. Per body donor, three CT scans were performed with the first acquisition carried out before contrast agent administration followed by two more CT scans, one after the intra-arterial and one after the intravenous injection. Consequently, three corresponding sets of data (native/non-enhanced, arterial system, and arterial plus venous system) were available for each injected body donor (Fig. 1). After scanning, contrast media was flushed out of the vascular system through the injection of an ethanolic camphor solution (99% ethanol) employing the same pneumatically-driven pump. Subsequently, the body donors underwent the institute's standard embalming procedure. All CT data were transferred to life-size virtual dissection tables (Anatomege Table, Anatomage Inc., San Jose, CA, USA) and to computer workstations mounted next to the dissection tables with in-house developed image post-processing software (AnatomyMap [4]). Both hardware solutions allow DICOM data visualization as conventional cross-sectional planes and multiple renderings of 3-D reconstructions (Fig. 2).

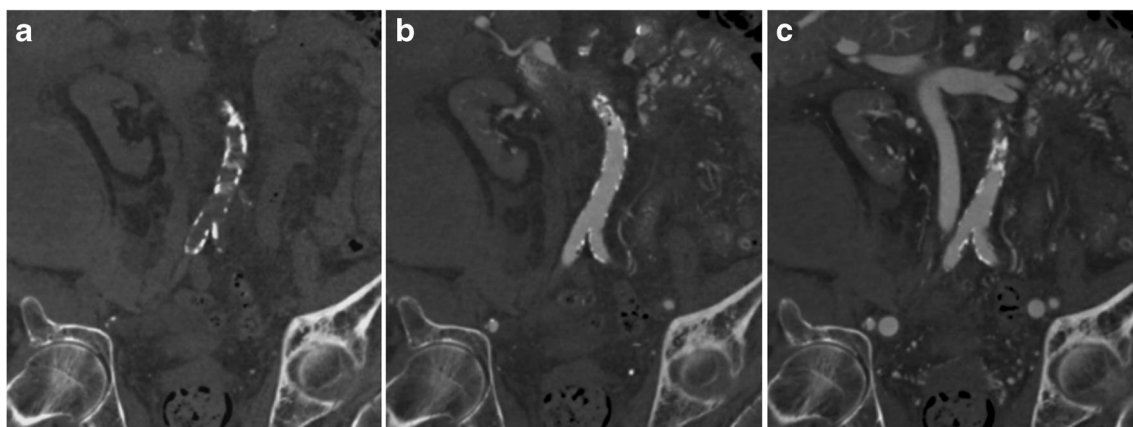


Fig. 1 Non-enhanced and contrast-enhanced cadaver-specific post-mortem CT (CEPMCT) in gross anatomy teaching: Coronal planes of a PMCT scan on bone window settings at the level of the aortic bifurcation of the same body donor. **(a)** Non-enhanced/native PMCT scan, aortic wall calcifications are displayed as hyperdense. **(b)** Intra-arterial contrast-

enhanced PMCT scan and **(c)** arterial-venous contrast-enhanced PMCT scan. Besides contrast-enhancement of the vascular system, also the attenuation of different tissues markedly improves at CEPMCT **(b, c)**. All images were rendered using the DICOM post-processing software Anatomy Map [4]

Study cohorts

Prior to the start of the winter semester 2016/17, 140 out of 400 first-year medical students were randomly invited to participate in this study. 132 students were enrolled in this prospective study after written informed consent was obtained. Fifty-nine (six groups of approximately ten) students were randomly assigned to the intervention group (IG) and provided with non-enhanced and contrast-enhanced cadaver-specific PMCT. Seventy-three (seven groups of approximately ten) students were randomly assigned to the control group (CG) and exclusively provided with NEPMCT scans of their body donors. Both groups could continuously access the provided CT scans of their body donor throughout the entire first-semester gross anatomy course. All students underwent tutor-guided virtual anatomy and radiological teaching sessions as described above. The seminars and teaching sessions were held by the same tutors for the intervention and control groups.

Quantitative analysis

Four multiple choice (MC) tests on the main course topics, each comprising 15 questions, were carried out within 1 week after the completion of a major subject: (1) extremities, (2) thorax, (3) abdomen, and (4) head and neck. The MC tests thorax and abdomen were merged, since these topics are treated in a combined module “situs”. The MC questions were composed of both image-based and theoretical questions with a special focus on the vascular system and its topographical anatomy. All MC exams were validated by two professors of radiology (H.S. > 25 years and F.G. > 20 years of experience in diagnostic radiology) and a professor of anatomy (T.K. > 25 years of experience in anatomy teaching). Image-based questions were generated from cross-sectional fresh-frozen human cadaver specimens (Anatamage Table, Anatamage Inc., San Jose, CA, USA), which neither group had worked with or seen before. Questions containing images from CE CT scans were

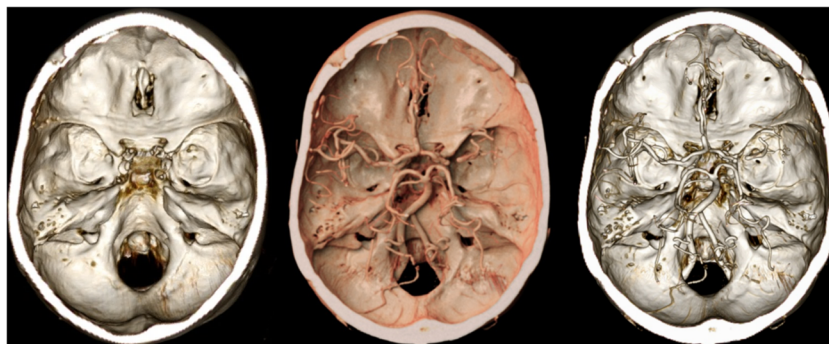


Fig. 2 Volume rendering techniques of non-enhanced and contrast-enhanced post-mortem CT at the level of the cranial base: 3-D renderings of a body donor before contrast agent administration (left) and after contrast administration (middle and right) showing cerebral arteries. Left: Non-enhanced at hard opaque shaded surface display (SSD). Middle and

Right: Contrast-enhanced image at hard opaque (uniform) SSD (middle) hard opaque SSD (right) showing cerebral arteries with a dominant right vertebral artery. All images were rendered using the Anatamage virtual dissection table (Anatamage Inc., San Jose, CA, USA)

explicitly avoided, since visual graphic memory could have positively biased the performance of the intervention group. All tests performed during this study were not relevant for the final grade of the student or his/her successful course completion. Median test results and interquartile range (IQR) in each subcategory were compared between the groups by using the Wilcoxon rank-sum test after normality test (Shapiro-Wilk) failed. Due to multiple testing (two groups, four MC tests), the significance levels were Bonferroni-corrected to $\alpha=0.05/4=0.125$. Statistical analyses were carried out with SigmaPlot version 12.5 (SystatSoftware, Inc., San Jose, CA, USA).

Qualitative analysis

After having completed the first semester course of human gross anatomy, participants of the intervention group were invited to fill out a 15-item questionnaire based on a five-point Likert scale (1=full disagreement, 2=partial disagreement, 3=neutral/indifference, 4=partial agreement, 5=full agreement). For each question the overall agreement (OA) was calculated. OA was defined as the number of students that stated partial and full agreement per question, divided by the number of students who answered the questionnaire. Furthermore, the median response was calculated for each question.

Results

Quantitative analysis

The intervention group achieved significantly higher median scores in head and neck anatomy (median=12.0, IQR=10.0–13.0) compared to the control group (median=10.5, IQR=9.0–12.0) ($p=0.009$). No significant differences were observed in the comparison of the MC tests of the other anatomical modules: Extremities (IG: median=11.0, IQR=9.75–12.0; CG: median=11.0, IQR=9.25–13.0), thorax (IG: median=11.0, IQR=9.0–12.0; CG: median=11.0, IQR=10.0–13.0), and abdomen (IG: median=9.0, IQR=9.0–10.0; CG: median=9.0, IQR=8.0–10.0) ($p>0.05$) (Fig. 3).

Qualitative analysis

In total, 53 out of 59 students of the intervention group answered the 15-item questionnaire (Fig. 4). Of the participants, 92.5 % recognized a significant difference between CEPMCT and NEPMCT and 71.7 % found the CEPMCT data sets enabled them a better differentiation of anatomical structures. Moreover, 94.3 % of the students stated that CEPMCT particularly improved their understanding of the vascular system. Accordingly, 5.7 % believed that there was no difference in the use of non-enhanced or contrast-enhanced PMCT regarding the teaching benefit in gross anatomy. Of the students,

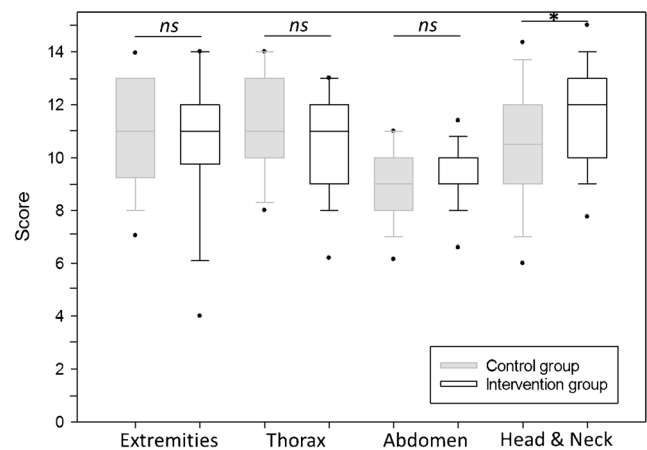


Fig. 3 Quantitative analysis: Boxplot of the results from four written MC-tests on the anatomical topics extremities/thorax/abdomen/head and neck. The intervention group achieved significantly higher median scores compared to the control group in the subcategory head and neck anatomy. Significant differences are indicated as *: $p < 0.05$; ns = not significant. Median test results were compared between the two groups for each anatomical module by using the Wilcoxon rank-sum test with Bonferroni's correction. Dots above/below the whisker lines represent the 5th and 95th percentile of outliers. All MC-tests included 15 questions with a special focus on vascular anatomy. Total teaching hours were equivalent for both groups

86.8 % used both CT data sets during the dissection time autonomously; 94.3 % agreed that in particular CEPMCT was useful; 25.5 % answered that both PMCT data sets were equally helpful; and 25.0 % stated that in particular the non-enhanced PMCT was supportive.

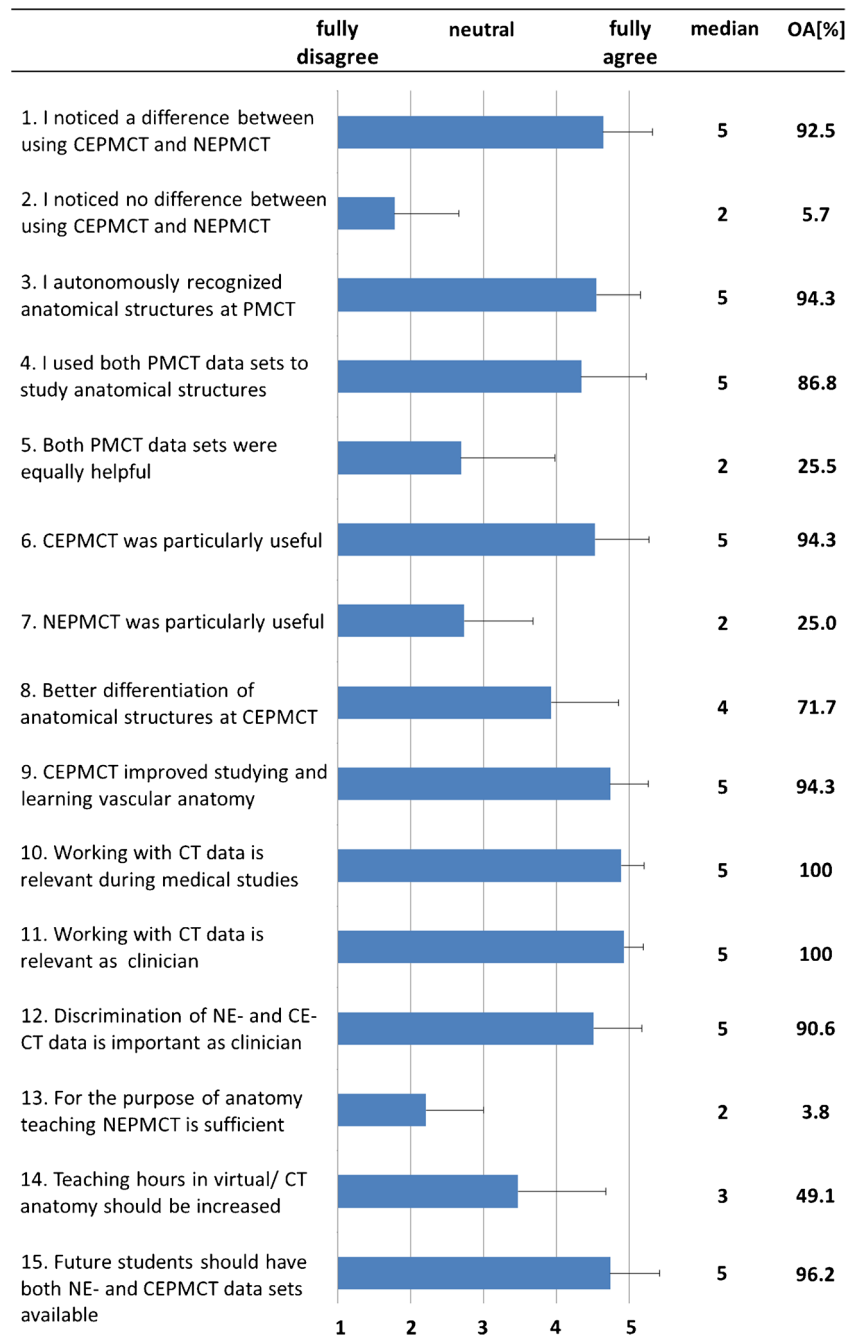
All participants (100 %) agreed that the handling of CT data sets is relevant during and after medical studies. Furthermore, 90.6 % agreed that the discrimination of the information provided by non-enhanced and contrast-enhanced CT is crucial for clinical practice; 49.1 % stated that the current curriculum should be extended by even more lessons in virtual anatomy. A large majority (96.2 %) expressed the opinion that future first-year medical students should have both contrast-enhanced and non-enhanced PMCT data sets of their body donor available. The results of the feedback-questionnaire are summarized in Fig. 4.

Discussion

In this study we show that the incorporation of contrast-enhanced cadaver-specific post-mortem computed tomography (CEPMCT) is feasible in the framework of a medical curriculum and yields improved learning performance, particularly in head and neck anatomy. First-year medical students highly appreciated CEPMCT used in tutor- or self-guided modes.

During the last few decades, a large variety of new technologies and teaching approaches has been introduced in the anatomy class, comprising radiological imaging modalities

Fig. 4 Qualitative analysis: Study questionnaire on the use of contrast-enhanced cadaver-specific post-mortem CT (CEPMCT) in gross anatomy teaching. Questions 1–15 were answered by 53/59 students of the intervention group. The bar graph displays the mean value of all answers; positive error bars indicate the standard deviation. Overall agreement (OA) was defined as fraction of all full (5) and partial (4) agreements divided by the number of all participating students. The median is additionally provided. The new teaching method was highly appreciated and well utilized by first-year medical students



(CT/ MRI/ ultrasound), interactive multimedia approaches and 3D-printing technologies [13–17]. Particularly, the combination of manual body dissection and radiological image interpretation has been proven to yield improved anatomy learning performance of undergraduate medical students [4, 6, 15, 18]. Moreover, several studies reported that working with radiological images increases students' motivation and that the involvement of patient cases highlights the clinical relevance of well-founded anatomical knowledge [13, 19–22]. Thus, our study is consistent with these experiences

and significantly extends the existing repertoire of radiology techniques used in gross anatomy teaching.

Using NEPMCT, benefits in learning performance were particularly reported for complex anatomical regions, with strongest gains in extremities and head and neck anatomy [4, 6]. In this work, students trained with cadaver-specific CEPMCT data performed significantly better in head and neck anatomy than a control group following the same course curriculum using NEPMCT data. In this context, one key advantage of CEPMCT is the good filling of precerebral and

intracerebral arteries and that the 3D-visualization enables tracing of complex arterial geometrics, consistent with the findings of Burgier et al., who reported complete fillings of the precerebral and intercerebral arteries in 49 retrospectively analysed CEPMCT scans [23].

Besides gains in vascular anatomy, CEPMCT also improved soft tissue attenuation. The parenchyma of solid organs was visibly enhanced compared to the native scans, already during intra-arterial injection, but most clearly after arterial and venous injection (Fig. 1). Consequently, image quality of post-mortem CT benefits from contrast media application.

Recently, we showed that training with cadaver-specific NEPMCT scans improved students' learning performance in the anatomy of the extremities [4]. In the present work, no significant difference in learning performance was observed for this anatomical subject between students working with CEPMCT or NEPMCT. In our opinion, strongest gains in this subject may result from studying cross-sectional visualizations of the musculoskeletal system and less so from visualizing the vasculature. In this regard, the additional value provided by CEPMCT compared to NEPMCT is limited, since image quality is predominantly affected by the amount of intermuscular fat tissue that separates neighbouring muscles.

The intervention group showed a tendency towards better results in the module abdomen and no improvements compared to the control group in the MC test on thorax. From

the radiologist's perspective, this result might appear counter-intuitive. PMCT scans, however, show artifacts due to body decomposition, particularly in thoracic organs, which complicate the image interpretation (Fig. 5) [20, 23, 24].

In 2011, Kourdioukova et al. reported that 78 % of European medical schools used radiological images in the first years of studies [25]. The role of radiologists in anatomy teaching is expected to further increase in the future, because there is general consensus that it is reasonable to learn how to interpret radiological image data at an early stage of studies, and to link the cross-sectional and 3D-visualization techniques with gross anatomy teaching. The students surveyed in our study shared this opinion and, consequently, a large majority agreed that future classes should include both contrast-enhanced and non-enhanced cadaver-specific PMCT data sets.

There are some limitations to this study: (1) Contrast agent application might influence dissection conditions. Since the vascular system of all body donors was flushed with ethanol, only marginal residues remain in the blood vessels. Therefore, no negative influence on the embalming and dissection procedure was noticed in all dissected cadavers. (2) The number of questions used in the MC tests appears relatively low. Nevertheless, statistically meaningful differences were observed in head and neck anatomy. For the abdomen, however, we would expect a larger group of students and higher number of questions to yield significant differences. (3) There are high

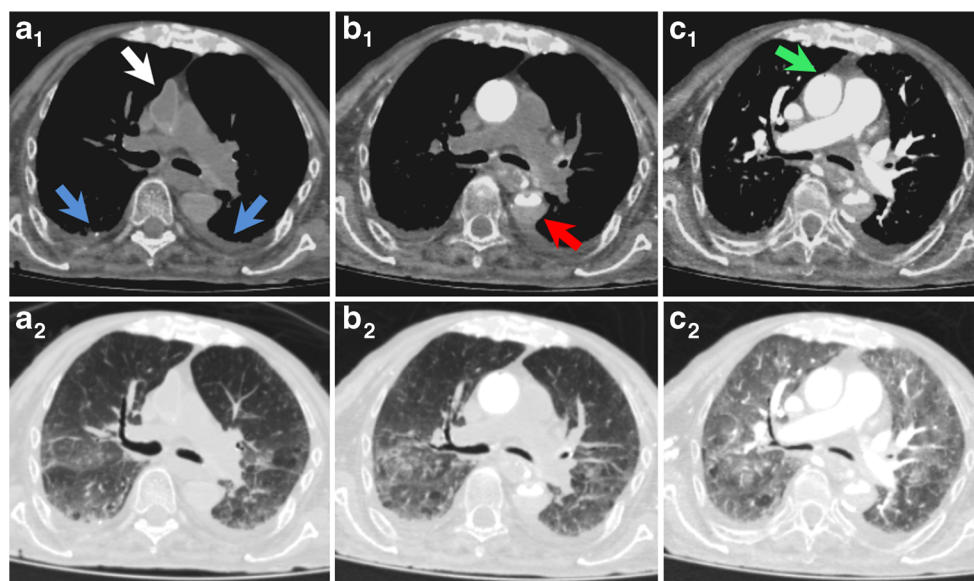


Fig. 5 Post-mortem artifacts in thoracic organs at contrast-enhanced cadaver-specific post-mortem CT (CEPMCT). Transversal planes of a CEPMCT scan of the same body donor on soft tissue window (top row) and lung window (bottom row) at the level of the pulmonary trunk. (a) Non-enhanced/native PMCT, (b) intra-arterial contrast-enhanced PMCT scan and (c) arterial-venous contrast-enhanced PMCT scan. Images show artifacts of thoracic organs commonly seen at CEPMCT: Small bilateral pleural effusions (blue arrows; a₁), collapsed ascending aorta (white

arrow; a₁), partial perfusion defect of the descending aorta (red arrow, a₂), and small arterial air emboli in the ascending aorta (green arrow, a₃). The collapsed ascending aorta re-expands during intra-arterial contrast injection (b₁). A bilateral attenuation gradient is discernible in the dorsal lung regions caused by post-mortem hypostasis (b₂). Moreover, extravasation of contrast agent into lung parenchyma can be observed during intra-arterial (b₂) and intravenous injection (c₂) due to increased capillary permeability after death

costs associated with a full implementation of CE/NEPMCT, requiring both human and material resources [4], which might limit an immediate applicability at some universities. However, costs can be reduced markedly through the acquisition of CE/NEPMCT in radiology departments at appropriate time slots and DICOM data sets can be visualized on conventional computers using free software solutions.

In conclusion, the introduction of contrast-enhanced cadaver-specific PMCT in medical education represents an important step forward in interweaving radiology and preclinical anatomy teaching. We demonstrated that the newly introduced teaching method yields improved learning performance and is highly appreciated by medical students. CEPMCT should therefore be considered to be part of the standard gross anatomy curriculum. Hence, CEPMCT represents a valuable addition of the standard gross anatomy curriculum.

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Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Dr. Daniel Paech.

Conflict of interest The authors of this manuscript declare no relationships with any companies whose products or services may be related to the subject matter of the article.

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Ethical approval Institutional Review Board approval was obtained.

Informed consent Written informed consent was obtained from all subjects in this study.

Methodology

- prospective
- randomised controlled trial
- performed at one institution

References

1. McNiesh LM, Madewell JE, Allman RM (1983) Cadaver radiography in the teaching of gross anatomy. *Radiology* 148:73–74
2. Chew FS, Relyea-Chew A, Ochoa ER Jr (2006) Postmortem computed tomography of cadavers embalmed for use in teaching gross anatomy. *J Comput Assist Tomogr* 30:949–954
3. Buenting M, Mueller T, Raupach T et al (2016) Post mortem CT scans as a supplementary teaching method in gross anatomy. *Ann Anat* 208:165–169
4. Paech D, Giesel FL, Unterhinninghofen R, Schlemmer HP, Kuner T, Doll S (2017) Cadaver-specific CT scans visualized at the dissection table combined with virtual dissection tables improve learning performance in general gross anatomy. *Eur Radiol* 27: 2153–2160
5. Jacobson S, Epstein SK, Albright S et al (2009) Creation of virtual patients from CT images of cadavers to enhance integration of clinical and basic science student learning in anatomy. *Medical Teacher* 31:749–751
6. Lufler RS, Zumwalt AC, Romney CA, Hoagland TM (2010) Incorporating radiology into medical gross anatomy: does the use of cadaver CT scans improve students' academic performance in anatomy? *Anat Sci Educ* 3:56–63
7. Bohl M, Francois W, Gest T (2011) Self-guided clinical cases for medical students based on postmortem CT scans of cadavers. *Clin Anat* 24:655–663
8. Grabherr S, Doenz F, Steger B et al (2011) Multi-phase post-mortem CT angiography: development of a standardized protocol. *Int J Legal Med* 125:791–802
9. Ross S, Spendlove D, Bolliger S et al (2008) Postmortem whole-body CT angiography: evaluation of two contrast media solutions. *Am J Roentgenol* 190:1380–1389
10. Jackowski C, Sonnenschein M, Thali MJ, et al (2005) Virtopsy: postmortem minimally invasive angiography using cross section techniques—implementation and preliminary results *J Forensic Sci* 50(5):1175–86
11. Grabherr S, Gygax E, Sollberger B et al (2008) Two-step postmortem angiography with a modified heart–lung machine: preliminary results. *Am J Roentgenol* 190:345–351
12. Riederer BM, Hoffer N, Hugonnet I et al (2016) Postmortem angiography for medical education. In: Grabherr S, Grimm JM, Heinemann A (eds) *Atlas of postmortem angiography*. Springer International Publishing, Cham, pp 531–551
13. Sugand K, Abrahams P, Khurana A (2010) The anatomy of anatomy: a review for its modernization. *Anat Sci Educ* 3:83–93
14. Benninger B, Matsler N, Delamarer T (2014) Classic versus millennial medical lab anatomy. *Clin Anat* 27:988–993
15. Miles KA (2005) Diagnostic imaging in undergraduate medical education: an expanding role. *Clin Radiol* 60:742–745
16. Rengier F, Mehndiratta A, von Tengg-Kobligk H et al (2010) 3D printing based on imaging data: review of medical applications. *Int J Comput Assist Radiol Surg* 5:335–341
17. Estevez ME, Lindgren KA, Bergethon PR (2010) A novel three-dimensional tool for teaching human neuroanatomy. *Anat Sci Educ* 3:309–317
18. Reeves RE, Aschenbrenner JE, Wordinger RJ, Roque RS, Sheedlo HJ (2004) Improved dissection efficiency in the human gross anatomy laboratory by the integration of computers and modern technology. *Clin Anat* 17:337–344
19. Estai M, Bunt S (2016) Best teaching practices in anatomy education: a critical review. *Ann Anat* 208:151–157
20. Slon V, Hershkovitz I, May H (2014) The value of cadaver CT scans in gross anatomy laboratory. *Anat Sci Educ* 7:80–82
21. Rengier F, Doll S, von Tengg-Kobligk H, Kirsch J, Kauczor H-U, Giesel F (2009) Integrated teaching of anatomy and radiology using three-dimensional image post-processing. *Eur Radiol* 19:2870–2877
22. Rizzolo LJ, Stewart WB, O'Brien M et al (2006) Design principles for developing an efficient clinical anatomy course. *Medical Teacher* 28:142–151
23. Bruguier C, Mosimann PJ, Vaucher P et al (2013) Multi-phase postmortem CT angiography: recognizing technique-related artefacts and pitfalls. *Int J Legal Med* 127:639–652
24. Filograna L, Thali MJ (2017) Post-mortem CT imaging of the lungs: pathological versus non-pathological findings. *Radiol Med* 122(12):902–908
25. Kourdioukova EV, Valcke M, Derese A, Verstraete KL (2011) Analysis of radiology education in undergraduate medical doctors training in Europe. *Eur J Radiol* 78:309–318