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**TECHNICAL NOTE**

*Christian Jackowski,*[1,2] *M.D.; Anders Persson,*[2] *M.D., Ph.D.; and Michael J. Thali,*[1] *M.D.*

# Whole Body Postmortem Angiography with a High Viscosity Contrast Agent Solution Using Poly Ethylene Glycol as Contrast Agent Dissolver

**ABSTRACT:** Postmortem minimal invasive angiography has already been implemented to support virtual autopsy examinations. An experimental approach in a porcine model to overcome an initially described artificial tissue edema artifact by using a poly ethylene glycol (PEG) containing contrast agent solution showed promising results. The present publication describes the first application of PEG in a whole corpse angiographic CT examination. A minimal invasive postmortem CT angiography was performed in a human corpse utilizing the high viscosity contrast agent solution containing 65% of PEG. Injection was carried out via the femoral artery into the aortic root in simulated cardiac output conditions. Subsequent CT scanning delivered the 3D volume data of the whole corpse. Visualization of the human arterial anatomy was excellent and the contrast agent distribution was generally limited to the arterial system as intended. As exceptions an enhancement of the brain, the left ventricular myocardium and the renal cortex became obvious. This most likely represented the stage of centralization of the blood circulation at the time of death with dilatation of the precapillary arterioles within these tissues. Especially for the brain this resulted in a distinctively improved visualization of the intracerebral structures by CT. However, the general tissue edema artifact of postmortem minimal invasive angiography examinations could be distinctively reduced.

**KEYWORDS:** forensic science, postmortem angiography, forensic radiology, digital autopsy, virtopsy, minimally invasive autopsy, postmortem imaging, imaging autopsy, computed tomography, poly ethylene glycol

Forensic postmortem investigations are increasingly supported by modern cross section techniques such as multislice computed tomography (MSCT) and magnetic resonance imaging (MRI). The advantages for the documentation of macromorphology in osseous and gaseous findings using MSCT (1–3) and in soft tissue pathology using MRI (4–7) were already discussed. Unenhanced postmortem imaging was described to be not sufficient in visualization of vascular pathology and was limited to the demonstration of major vessel injuries (8,9). To overcome this limitation a minimal invasive angiography technique using an iodinated contrast agent and MSCT was implemented (10,11). An excellent three-dimensional (3D) visualization of the entire arterial system could be shown in a minimal invasive manner as it was intended. However, as an artifact of the presented method, an increase of tissue edema signs in histological investigations became obvious in some cases (10).

In a following experimental study on a porcine heart model it was shown that an increase of the contrast agent's viscosity can prevent it from a distribution within the capillary bed and thereby, from leaving the vascular system and causing edema artifacts (12). This was explained by the increase of flow resistance within the vessels of small diameter due to the increased viscosity at stable injection pressure conditions (<60 mmHg). For the left ventricular porcine myocardium a viscosity of 15 mPas was shown to be sufficient. Instead of solely lipophilic dissolving agents, for which vessel wall interactions in regions with atheromatosis have already be described decades ago (13,14), poly ethylene glycol (PEG) was chosen as a contrast agent dissolver as it has an increased intrinsic viscosity and can dissolve the used aqueous contrast medium.

The next consecutive step was to test its feasibility and performance on a human corpse.

[1]Center for Forensic Imaging and Virtopsy, Institute of Forensic Medicine, University of Bern, Bühlstr. 20, 3012 Bern, Switzerland.

[2]Center for Medical Image Science and Visualization, CMIV, University of Linköping, 58185 Linköping, Sweden.

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## Materials and Methods

In close collaboration with the Institute of Human Anatomy, University of Bern, an unfixed human corpse underwent the following procedures. Preparation of the corpse was carried out according to the initial study published in 2005 (10), namely an access to the ascending aorta via the right femoral artery as well as an access to the left femoral artery for pressure control were prepared. Also the injection procedure was not changed and consisted of an injection of a contrast agent volume slightly more than the expected arterial blood volume with a flow adapted to the vital cardiac output as far as not to exceed 60 mmHg intravascular pressure supervised with a conventional manometer via the left femoral access. According to the results from the porcine heart study we used a PEG (PEG-200; Schärer und Schläpfer AG, Rothrist, Switzerland) concentration of 65% resulting in an approximated viscosity of 18 mPas. Prior to injection the corpse was turned several times to redissolve the sedimented cellular blood components.

The scanner settings differed slightly as a different CT scanner was used (Emotion 6; Siemens Medical, Erlangen, Germany). Raw data acquisition was performed with the following settings: 110 kV; 100 mAs; collimation $6 \times 1$ mm and $6 \times 0.5$ mm. Image reconstruction was carried out in slice thicknesses of 1.25 and 0.625 mm, each with an increment of half the slice thickness, B30

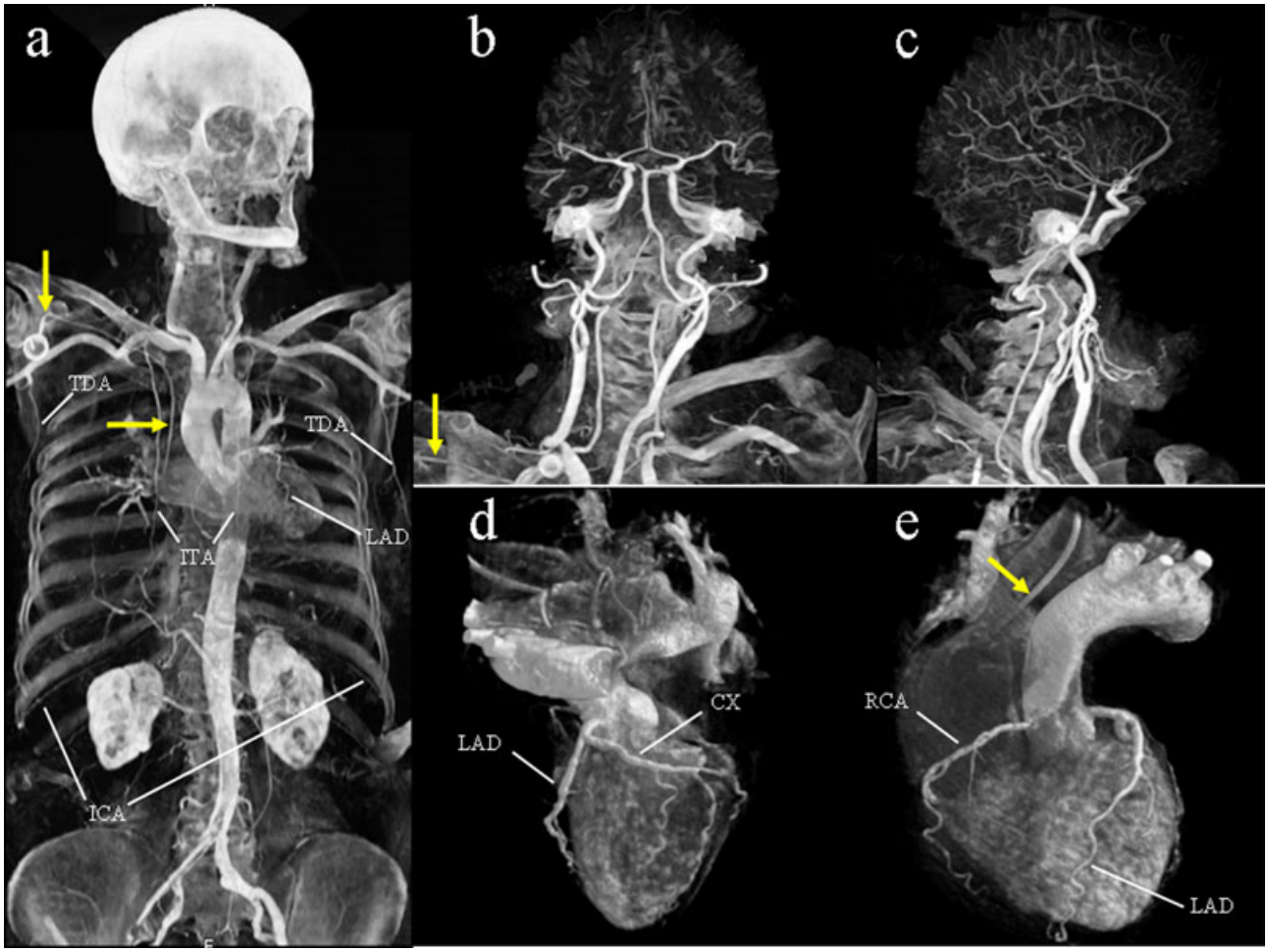


FIG. 1—*3D visualization of the arterial system in a corpse by CT and high viscosity contrast agent injection: (a) AP view focused on the head and trunk of the whole corpse angiography. Normal human arterial anatomy is demonstrated including also small branches such as the thoracodorsal arteries (TDA), the intercostal arteries (ICA), the internal thoracic arteries (ITA), or the coronary arteries (LAD—left anterior descending coronary artery). Note also a central venous port system (yellow arrows). (b + c) Magnification and removal of the skull bone provides an insight on the intra cranial arteries in a slight oblique AP view (b) and a right lateral view (c). Note the excellent representation of the entire cerebral arterial system until the most peripheral branches. (d + e) Magnification and removal of the surrounding tissues reveal normal coronary artery anatomy (LAD—left anterior descending coronary artery; CX—circumflex coronary artery; RCA—right coronary artery). Neither relevant narrowing nor stenoses are present, but an obvious screw-like epicardial course of the LAD and of the posterolateral branches of the circumflex coronary artery is demonstrated strongly indicating a chronic hypertonia.*

reconstruction kernel, matrix 512, and different field of views (FoV) including an extended FoV of 700 mm.

## Results

First of all, the injection process in the present study much benefited from the increased viscosity as it was distinctively easier to maintain the 60 mmHg injection pressure compared to use of the initially published low viscosity contrast agent solution (10).

The minimal invasive whole corpse angiography with PEG as contrast agent dissolver provided an excellent demonstration of the arterial system of the corpse in 3D (Fig. 1). Also the intra cranial vessels and the coronaries were displayed until smallest branches such as septal and posterolateral branches of the coronaries. None of the artifacts due to vulnerable vessels as described within the initial study (10) occurred such as an enhancement of the pancreas or the contrast agent entering the bowel lumen.

There was no general distribution of contrast agent within the capillary bed of the body tissues as a result of the increased viscosity. However, three exceptions could be recognized. The renal cortex, the left ventricular myocardium, and the brain became enhanced. For the brain the enhancement distinctively improved its visualization using CT. Shown in Fig. 2 the injected contrast agent enhanced specifically the white matter of the brain clearly depicting the border between white and gray matter and thereby giving an accurate anatomical visualization of the brain structures in CT. Also the cerebellum was sharply outlined (Fig. 2*c*).

## Discussion

For the demonstrated angiography a contrast agent solution with increased viscosity was used. That resulted in several advantages for the overall feasibility of the minimal invasive postmortem angiography approach.

First of all, during injection the suggested 60 mmHg injection pressure was quickly reached and could easily be maintained with less flow. As less volume could get lost within the interstitial spaces the overall volume to be injected was only slightly more than the expected arterial blood volume of the corpse. Compared to the low viscosity solution, the overall injected contrast agent volume could be distinctively reduced as one injection was sufficient.

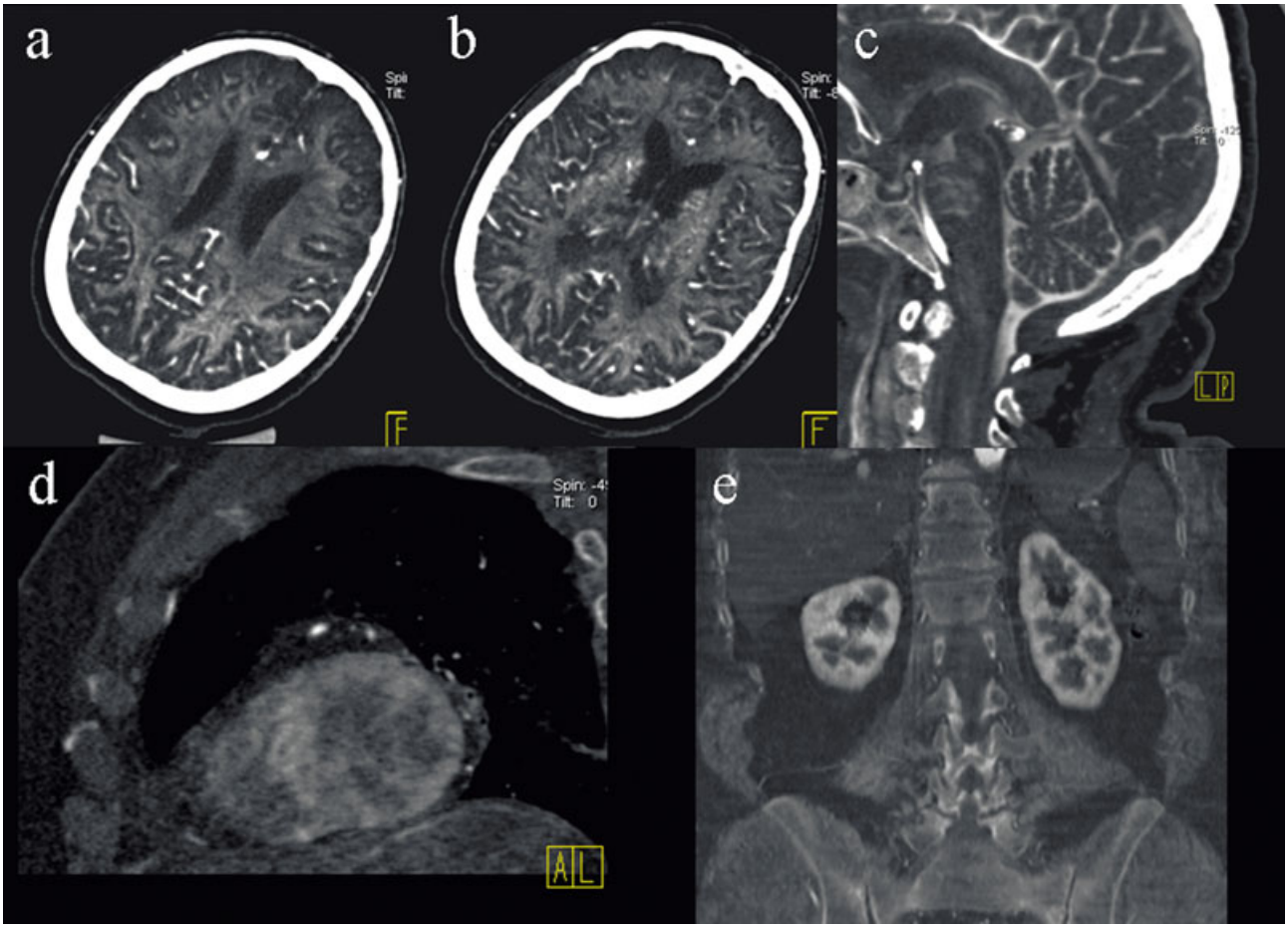


FIG. 2—*Selective soft tissue enhancement that could only insufficiently be reduced by the increase of contrast agent viscosity demonstrating the centralization of the circulation at the time of death: (a + b) Cross sectional CT images of the brain at different levels show a strong white matter enhancement clearly depicting the border between white and grey matter. (c) Sagital CT image sharply outlining the cerebellum. (d) Short axis image of the heart shows circular left myocardial enhancement. (e) Coronal lumbal CT image demonstrates distinctive enhancement of the renal cortex.*

As the study intended on an improvement of the vessel diagnostics in CT we unexpectedly recognized a distinctively enhanced brain visualization within the CT images. An assessment of the anatomical structures of the brain and cerebellum was provided that has so far only been reached with the use of MRI. Since this is much more elaborate in use and usually requires more efforts for a forensic institution to get access to it, one should be aware of this possibility to increase brain diagnostics in CT.

It became obvious that the contrast agent distribution varied in different body regions and organs in terms of distribution within the capillary bed. In general, the contrast agent distribution was limited to the arterial system without the capillary bed as a result of the increase of viscosity as it was intended. However, there were exceptions. Besides the brain, also the renal cortex showed enhancement. Furthermore and in contrast to the porcine heart experiments the left ventricular myocardium of the corpse became enhanced too. For the brain, the renal cortex, and the left ventricular myocardium the centralization of the circulation with maximal dilation of the arterioles in these organs during the dying process might be the most obvious causation. The postmortem angiography can thereby give a visual impression of the centralization effects on the local blood supply of these organs. As the enhancement of the brain was strongly specific within the white matter the slight amphiphilic nature of the PEG might have contributed to the enhancement of the brain too.

We stated in the experimental porcine heart study that it might be necessary to define an adequate contrast medium viscosity for the corpse under consideration of all human soft tissues as we expected local differences of the flow resistance in different soft tissues (12). The results of the present study partially support this as there were local differences in flow resistance. Otherwise, the used viscosity worked very well and the local enhancement of the three organs seems not to be a technique-related artifact but rather displays a local change in blood circulation at the time of death that was kept postmortem. Therefore we can conclude that the used 18 mPas viscosity could be used for further feasibility studies in larger study groups (at 20°C room temperature).

Besides its general use within the idea of the minimal invasive virtual autopsy the technique could be particularly helpful as an autopsy supporting tool in cases of malpractice in surgery, when small vessel lesions as a bleeding source need to be visualized, when cardiac vessel dissection at autopsy is expected to be complicated such as after one or two coronary bypass graft surgeries, or in suspected cases of aneurism caused subarachnoid hemorrhage.

## Conclusion

The visualization of the arterial system was excellent and the contrast agent distribution within the soft tissues of the body was

distinctively reduced by the use of the high viscosity PEG solution. Exceptional soft tissue enhancement most likely demonstrates local increase in blood supply by dilatation of precapillary arterioles at the time of death.

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## References

1. Jackowski C, Thali M, Sonnenschein M, Aghayev E, Yen K, Dirnhofer R, et al. Visualization and quantification of air embolism structure by processing postmortem MSCT data. J Forensic Sci 2004;49(6):1339–42.
2. Shiotani S, Kohno M, Ohashi N, Yamazaki K, Nakayama H, Watanabe K, et al. Non-traumatic postmortem computed tomographic (PMCT) findings of the lung. Forensic Sci Int 2004;139(1):39–48.
3. Thali MJ, Braun M, Buck U, Aghayev E, Jackowski C, Vock P, et al. VIRTOPSY–scientific documentation, reconstruction and animation in forensic: individual and real 3D data based geometric approach including optical body/object surface and radiological CT/MRI scanning. J Forensic Sci 2005;50(2):428–42.
4. Thali MJ, Yen K, Schweitzer W, Vock P, Boesch C, Ozdoba C, et al. Virtopsy, a new imaging horizon in forensic pathology: virtual autopsy by postmortem multislice computed tomography (MSCT) and magnetic resonance imaging (MRI)—a feasibility study. J Forensic Sci 2003;48(2):386–403.
5. Patriquin L, Kassarjian A, Barish M, Casserley L, O'Brien M, Andry C, et al. Postmortem whole-body magnetic resonance imaging as an adjunct to autopsy: preliminary clinical experience. J Magn Reson Imaging 2001;13(2):277–87.
6. Jackowski C, Schweitzer W, Thali M, Yen K, Aghayev E, Sonnenschein M, et al. Virtopsy: postmortem imaging of the human heart in situ using MSCT and MRI. Forensic Sci Int 2005;149(1):11–23.
7. Dirnhofer R, Jackowski C, Vock P, Potter K, Thali MJ. VIRTOPSY: minimally invasive, imaging-guided virtual autopsy. Radiographics 2006;26(5):1305–33.
8. Shiotani S, Watanabe K, Kohno M, Ohashi N, Yamazaki K, Nakayama H. Postmortem computed tomographic (PMCT) findings of pericardial effusion due to acute aortic dissection. Radiat Med 2004;22(6):405–7.
9. Aghayev E, Thali MJ, Sonnenschein M, Hurlimann J, Jackowski C, Kilchoer T, et al. Fatal steamer accident; blunt force injuries and drowning in post-mortem MSCT and MRI. Forensic Sci Int 2005;152(1):65–71.
10. Jackowski C, Sonnenschein M, Thali MJ, Aghayev E, Von Allmen G, Yen K, et al. Virtopsy: postmortem minimally invasive angiography using cross section techniques—implementation and preliminary results. J Forensic Sci 2005;50(5):1175–86.
11. Grabherr S, Djonov V, Friess A, Thali MJ, Ranner G, Vock P, et al. Postmortem angiography after vascular perfusion with diesel oil and a lipophilic contrast agent. AJR Am J Roentgenol 2006;187(5):W515–23.
12. Jackowski C, Bolliger S, Aghayev E, Christe A, Kilchoer T, Aebi B, et al. Reduction of postmortem angiography-induced tissue edema by using polyethylene glycol as a contrast agent dissolver. J Forensic Sci 2006;51(5):1134–7.
13. Schoenmackers J. Technik der postmortalen Angiographie mit Berücksichtigung verwandter Methoden postmortaler Gefässdarstellung. Ergeb Allg Pathol Pathol Anat 1960;39:53–151.
14. Frik W, Persch WF. The effect of contrast media type on the vascular caliber in experimental angiography. Fortschr Geb Rontgenstr Nuklearmed 1969;111(5):620–9.

Additional information and reprint requests:
Christian Jackowski, M.D.
University of Bern
Institute of Forensic Medicine
IRM, Buehlstrasse 20
CH 3012 Bern
Switzerland
E-mail: christian.jackowski@irm.unibe.ch