Journal of Forensic Radiology and Imaging 7 (2016) 38–42

Contents lists available at ScienceDirect

Journal of Forensic Radiology and Imaging

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

Post-mortem computed tomography angiography utilizing barium sulfate to identify microvascular structures: a preliminary phantom model and case study

Wieke Haakma[a,b,c,*], Marianne Rohde[a], Lidy Kuster[a,b], Lars Uhrenholt[a], Michael Pedersen[b], Lene Warner Thorup Boel[a]

[a] *Department of Forensic Medicine, Aarhus University, Aarhus, Denmark*
[b] *Department of Comparative Medicine Lab - Clinical Institute, Aarhus University, Aarhus, Denmark*
[c] *Department of Radiology, University Medical Center Utrecht, Utrecht, The Netherlands*

ARTICLE INFO

Keywords:
Forensic sciences
Post-mortem computed tomography angiography
Forensic radiology
Small vessels
Capillaries
Barium sulfate
Poly ethylene glycol
Micro vascular lesions
Histology

ABSTRACT

We investigated the use of computer tomography angiography (CTA) to visualize microvascular structures in a vessel-mimicking phantom and post-mortem (PM) bodies. A contrast agent was used based on 22% barium sulfate, 20% polyethylene glycol and 58% distilled water. A vessel-mimicking phantom identified small vessels. Intercostal arteries and veins were visualized in four males and one female without known vascular lesions. Histology confirmed the filling of vascular structures down to 8 μm without extravasation.

1. Introduction

In forensic practice, computed tomography angiography (CTA) is capable of identifying vascular lesions by injecting a contrast agent into a vessel. In post-mortem (PM) settings, different regions and conditions of the body have been investigated with this technique, including coronary arteries, esophageal varices, intracranial aneurysms and even the entire vascular system [1–3]. Small traumatic lesions and fractures as well as injured small vessels are easily overlooked during autopsy, although they may provide essential clinical information in a variety of cases. At present there is a general agreement that post-mortem computed tomography angiography (PMCTA) has great potential in the detection of small hemorrhages [4,5]. However, information about how small vascular lesions can be detected remains to be elucidated.

Different contrast agents have been applied in PMCTA [6], and the compositions of these agents have been based on, for example, aqueous or oily suspensions [3]. Aqueous suspensions have the advantage of visualizing the microcirculation but with extravasation as a drawback [6]. Extravasation of oily suspensions is less extensive than aqueous suspensions. However, due to an increased viscosity, a relatively high injection-pressure is necessary, which carries a risk of inflation of the perfused vessels [3]. Capillary leakages may occur if the pressure is too high and the contrast medium penetrates the intestinal lumen, which may lead to misinterpretation of the CT images [3]. Combining an aqueous contrast medium with polyethylene glycol (PEG) may overcome this problem [3,7,8]. As a radiopaque contrast medium, barium sulfate has been used in whole-body PMCTA [3]. However, the exact composition of barium sulfate in combination with PEG and its potential benefits in the visualization of microvascular lesions remain to be examined.

Phantoms are useful to mimic vascular and capillary networks. Boussion et al. utilized a phantom in order to measure vessel sizes, demonstrating a 7.5% underestimation of the smallest vessels (diameter of 0.93 mm) using x-ray angiography, whereas a 5.4% overestimation was reported with CTA [9]. Hence, phantoms aid in evaluating different compositions of contrast agents and to display to what extent small vessels are still recognizable.

The aim of this study was to assess the potential of a barium sulfate suspension in combination with PEG as a contrast agent to visualize the microvascular structures using PMCTA, both in a vessel-mimicking

* Corresponding author at: Depart ment of Forensic Medicine and Comparative Medicine Lab, Aarhus University, Palle Juul-Jensens Boulevard 99, 200 Aarhus N, Denmark.
E-mail address: whaa@clin.au.dk (W. Haakma).

http://dx.doi.org/10.1016/j.jofri.2016.11.003
Received 18 March 2016; Received in revised form 10 September 2016; Accepted 9 November 2016
Available online 16 November 2016
2212-4780/

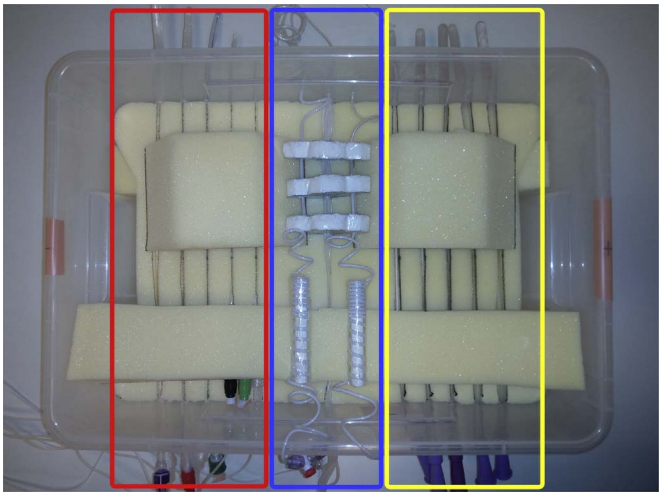

Fig. 1. : Multimodality vascular phantom to test for 3 physical parameters: part 1, in red, consists of different sizes of vessels, part 2, in blue, represents an anatomical mimic of vascular structures interacting with bone structures, part 3, in yellow, was built to test different concentrations of barium sulfate. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

phantom and in PM bodies.

2. Materials and methods

2.1. Vascular phantom

A vascular phantom was built (Fig. 1) to test the accuracy of CTA in detecting small vessel lesions. The phantom was designed to investigate three physical parameters related to the vascular system, which were examined at room temperature.

1) Effect of catheter size (Fig. 1, part 1)
   Different catheter sizes were used to investigate the smallest detectable vessel size using five silicone catheters (AquaFlate Glycerine Brilliant Foley catheter, Teleflex Medical Europe, Athlone, Ireland) with increasing outer diameters (2, 3.33, 4.67, 6 and 7.33 mm). The phantom was filled with a contrast agent, consisting of 22% barium sulfate (Mixobar, Bracco Imaging Scandinavis, Copenhagen, Denmark), 20% PEG (Polyethylene 200, Merck Millipore, Darmstadt, Germany) and 58% distilled water. Images were acquired immediately after preparation to prevent sedimentation.
2) Distinguishing vessels (Fig. 1, part 2)
   Seven tubes (Extension set, Codan Medical, Lensahn, Germany) with an inner diameter of 1 mm were bundled together. Plasterboard and chalk were used as surrogate for bone in the phantom. Bundles of tubes were lead through plasterboard to investigate if the identification of vascular structures is affected by neighboring dense structures (such as bone). Two tubes (MEDRAD Europe, Beek, The Netherlands) were wrapped around the chalk. The composition of the contrast agent was the same as used in part.
3) Effect of concentration of contrast agent (Fig. 1, part 3)
   Five polyvinyl tubes (Rectal Tube CH22, ConvaTec, Deeside, United Kingdom) with an outer diameter of 7.38 mm were used to test different concentrations of barium sulfate; 5%, 10%, 20%, 40%, and 60% (Mixobar Colon 1 g/ml) in combination with PEG and distilled water. The contrast agent suspension was mixed just before it was injected into the phantom. Hounsfield unit (HU) measurements were measured in small bottles with corresponding concentrations as this provided a more homogenous measurement.

2.2. Whole-body PMCTA

A modified heart lung machine was used to administer the contrast agent. A maximum allowed pressure of 50 mmHg was used [3,10]. Four males and one female without any known vascular lesions were included (mean age 36 years, range 21–48 years, with average of 4 days between death and scanning). Whole-body CTA examinations were performed with a standardized multiphase approach based on Grabherr et al. [11] using a Siemens Somatom Definition 64-row CT system. The contrast agent was at room temperature and CT scans were obtained before and after each phase. A contrast agent consisting of 22% barium sulfate, 20% PEG, and 58% distilled water was used to fill up the vascular system. PEG was added to increase viscosity and to reduce tissue edema [7]. Contrast agent suspension was mixed just before injection. The femoral artery and veins were catheterized and used as the entrance for the contrast agent administered by the modified heart lung machine. For the arterial phase we used approximately 1200 ml, for the venous phase 1600 ml and for the dynamic phase 500 ml. Images were acquired immediately after the injection to prevent sedimentation.

2.3. CT and image analysis

CT settings for both the phantom experiments and whole body angiographies were as follows: slice thickness 0.6 mm, 120 kV, tube current 88 eff, mAs 120 kV, and pitch 0.65. CT datasets of the vascular phantom were analyzed with the workstation software (Syngo CT 2012B, Somaris VA44). Multiplanar reconstructions (MPR) as well as volume rendering technique (VRT) images were obtained. CT images of the bodies were analyzed with the workstation software and Amira 5.3.3 software (VSG, Richmond, Australia) by two observers (one pathologist with 9 years of experience, and one researcher with 2.5 years of experience) qualitatively based on consensus reading. They observed the areas of vascular filling, the degree of vascular filling, as well as areas of possible contrast leakage. Tissue samples were taken from brain, heart, lung, kidney and liver and were stained in hematoxylin eosin after which they were evaluated during microscopic examination.

3. Results

3.1. Vascular phantom

1) Effect of catheter size using 22% barium contrast
   In part 1 of the phantom, using 22% barium contrast, all vessels including the smallest catheter (1 mm) were visible on the MPR images along the entire trajectory (Fig. 2). However, the smallest catheter could not be visualized along the entire trajectory as some parts were not visualized by VRT.
2) Distinguishing vessels using 22% barium contrast
   The bundle of tubes is shown in part 2 of the phantom, illustrating the difficulties in distinguishing the tubes from each other on the MPR and VRT image. Along the trajectory of the tubes, parts of the bundle appeared to have fused with each other. However, the tubes were well distinguishable from the simulated bone (i.e. plasterboard and chalk) using 22% barium contrast.
3) Effect of concentration of contrast agent
   Part 3 of the phantom showed the different concentrations of barium sulfate represented in the tubes. The tubes with concentrations of 5% and 10% barium sulfate showed that the suspension was not well distributed through the tube and showed higher HU at the tube wall, but higher concentrations of 40% and 60% showed scatter artifacts. A concentration of 20% provides good distribution and no scatter artifacts. Table 1 represents the HU corresponding to the different concentrations measured in bottles.