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# Fast three-dimensional whole-body post-mortem magnetic resonance angiography

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ABSTRACT

*Purpose:* The goal of this study was to perform whole-body post-mortem magnetic resonance (PMMR) angiography with imaging quality comparable to that of post-mortem computed tomography (PMCT) angiography.
*Methods:* After contrast medium injection into the arterial and venous vascular system of seven human corpses PMMR was performed using a fast three-dimensional T1 weighted spoiled gradient-echo sequence, followed by PMCT imaging. The contrast medium volumes inside the descending aorta and inside the inferior vena cava were measured both on PMMR and on PMCT images by means of image segmentation. Visualization quality of arterial and venous vessels as a function of contrast filling was scored according to a four-point scale and compared using the paired Wilcoxon signed rank test.
*Results:* The contrast medium volume in the descending aorta decreased 12% on average from PMMR to PMCT angiography, while the contrast medium volume in the inferior vena cava increased by 11% on average. A total of 410 vessels were analyzed. Scores for all vessels were statistically significantly smaller for the PMMR angiography when compared to PMCT angiography ($p = 0.01$). No statistically significant differences were found for the subgroups of large vessels ($p = 0.21$), for the head and neck ($p = 0.16$) or the abdomen ($p = 0.83$) as well as for the thorax when the coronary arteries were left out ($p = 0.23$).
*Conclusions:* This study demonstrates that immediate image acquisition after contrast injection and rapid 3D whole-body image acquisition offers good image quality in PMMR angiography with a vascular contrast comparable to PMCT angiography.

## 1. Introduction

In the last decade minimally invasive autopsy has become a field of intensive research activity with a focus on cross-sectional imaging techniques routinely used in clinical radiology such as computed tomography (CT) and magnetic resonance (MR) imaging [1–6]. These techniques can document forensically relevant data objectively and if necessary the digitally stored data can be reevaluated at a later time. Furthermore, minimally invasive autopsy may be an alternative in cases where there are religious objections against a conventional autopsy.

CT is the most commonly used cross-sectional imaging modality used, mostly because it is cheaper and image acquisition less complex and faster compared to MR [3]. However, unenhanced post-mortem CT (PMCT) provides only very limited soft-tissue contrast and its reliability in assessing the vascular system is poor [7]. Post-mortem MR (PMMR) [4,8–10] and PMCT angiography [7,11,12] have been introduced into forensic imaging to overcome these limitations. PMMR provides tremendously more soft-tissue detail than unenhanced PMCT and whole-body PMCT angiography is able to display the vascular system except for the portal venous system. Over the past years, several approaches have been developed for PMCT angiography and they vary regarding the site of vascular access (e.g. femoral or supraclavicular), contrast injection (e.g. electronic pump, CT injectors, manual injection, or chest compression), contrast type (negative or positive), contrast medium and solvent (e.g. hydrophilic or lipophilic), and contrast phases (single or multiple) [11–16].

Combining the soft-tissue detail provided by unenhanced PMMR imaging with information about the vascular system acquired by

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angiography would be very useful and could establish the MR scanner as a potential one-stop-shop for many forensic questions. An example might be to display an acute myocardial infarction best seen on T2 weighted PMMR images [10,17] in conjunction with the causative coronary artery occlusion seen in the PMMR angiographic images, both datasets being spatially co-registered. An early study by Ruder et al. compared PMMR to PMCT angiography in four adult human corpses [18]. They filled the arterial side of the vascular system with an iodinated contrast medium diluted in polyethylene glycol (PEG) via a femoral access, followed by first CT and second 2D MR imaging. Their conclusion was that PMMR angiography is technically feasible but that there was a significant decrease in intravascular contrast volume from PMCT to PMMR angiographic imaging with consequently inferior to absent display of some vessels. This loss of image quality was attributable to a significant time delay between PMCT and PMMR scanning of about 30 min, caused by the transport of the corpse from the CT to the MR scanner and by the relatively time-consuming PMMR protocol.

The goal of this study was to assess the effect of an immediate image acquisition after contrast medium injection as well as the use of fast three-dimensional (3D) MR sequences on overall image quality and vessel distension of PMMR angiography in comparison to PMCT angiography.

## 2. Materials and methods

### 2.1. Subjects

The study was approved by our institutional review board and the public prosecution department. PMMR angiography was performed on seven consecutive human corpses which had been delivered to our institute for forensic death investigation. Inclusion criteria were (1) vascular pathology and/or hemorrhage suspected based on routine unenhanced whole body PMCT, (2) no signs of decomposition on unenhanced whole body PMCT, (3) body weight below maximum MR table weight capacity of 225 kg, (4) age ≥ 18 years. The study population consisted of four men and three women with a mean age of 62 years (range 37–92 years). Causes of death included traffic accidents (cases 1, 5 and 6), ruptured intracranial aneurysms (cases 2 and 4), a ruptured visceral aneurysm (case 3) and an aortic dissection Stanford type A with rupture of the ascending aorta (case 7). The mean post-mortem interval (time interval between death and PMMR scanning) was 32 h (range 12–60 h).

### 2.2. Angiography workflow

Access to the vascular system via the femoral vessels, contrast medium injection into the vascular system and PMMR as well as PMCT imaging was performed according to the workflow shown in Fig. 1. Angiographic imaging was performed in two steps to acquire an arterial as well as a venous phase of angiography. In the arterial phase contrast medium was injected into the arterial side of the vascular system followed by PMMR and PMCT imaging, in the venous phase contrast medium was injected into the venous side, again followed by PMMR and PMCT imaging. Contrast medium injection immediately was followed by PMMR imaging and secondarily by PMCT imaging. The details of the workflow are shown in the following paragraphs.

### 2.3. Post-mortem angiography

Outside of the MR suite a right-sided vascular cut-down was performed to access the femoral vessels and two 14F plastic cannulae were deaerated and introduced into the femoral artery and vein in a caudal to cranial direction. The corpse was then moved into the MR suite and placed on the examination table in supine position. A roller pump of an out of service heart-lung machine was connected to the vascular cannula (in the arterial phase to the arterial cannula, in the venous phase to the venous cannula) via a 14 m long 0.25 in. plastic tube. The roller pump was positioned in the MR control room and the plastic tube was passed through a small opening in the wall of the MR suite. Four liters of a mixture of a hydrophilic iodinated contrast medium (Optiray 300, Guerbet, Zürich, Switzerland) and the solvent polyethylene glycol (PEG) (PEG 200, Schärer und Schläpfer AG, Rothrist, Switzerland) at a ratio of 1:13 were prepared in a plastic container. The mixture served as contrast medium for both PMMR and PMCT angiography. As described by Ruder et al. [18] the mixture has a T1 shortening effect similar to gadolinium. Therefore no gadolinium was used for PMMR angiography.

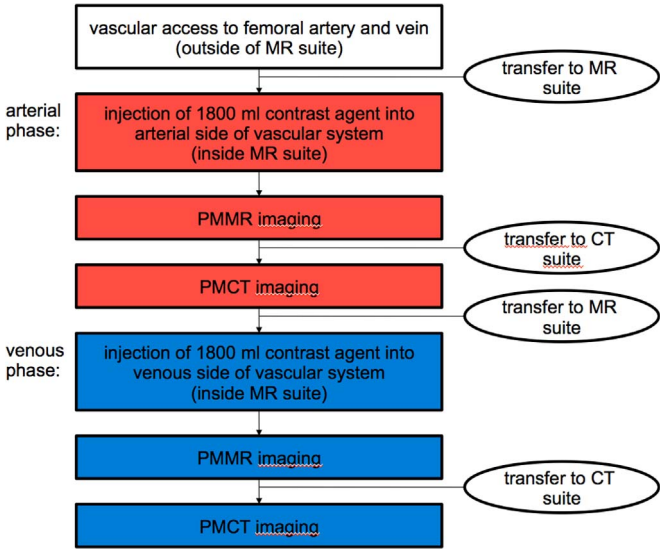


**Fig. 1.** Angiography and imaging workflow.

For each step 1800 ml of the contrast medium were injected at a flow rate of 600 ml/min previous to the acquisition of angiographic images, in keeping with [14].

### 2.4. PMMR imaging protocol

PMMR imaging was performed with a 3,0-Tesla MR scanner (Achieva 3.0 TX, Philips Medical System, Best, The Netherlands) using the built-in Q-Body coil and a rolling table platform. Before contrast medium injection an unenhanced whole-body PMMR was performed using coronal STIR and axial T2 sequences, all with a slice thickness of 5 mm, as recommended in the literature [4].

For PMMR angiography a fast 3D T1 weighted spoiled gradient-echo sequence with the following parameters was used: TR = 5.1 ms, TE = 1.6 ms, flip angle = 30°, number of signal averages = 1, field of view = 450 × 398 × 180 mm, voxel size = 0.78 × 0.78 × 1.5 mm and reconstruction matrix = 576 × 576. The imaging volumes were coronally oriented to give maximum coverage of the vascular system. First the superior station (head, neck and thorax) was acquired, followed by the inferior station (abdomen and pelvis) with a 50 mm overlap between the stations as shown in Fig. 2. Acquisitions were performed both before and after contrast medium injection.

Acquisition time for the whole-body sequences was about 60 min, for the angiographic sequences about 60 s per station, resulting in about two minutes acquisition time each before and immediately after contrast medium injection for the two stations.

After completion of the PMMR angiography the femoral cannulae were disconnected from the roller pump and sealed and the corpse was moved to the adjacent CT suite.

### 2.5. PMCT imaging protocol

The corpses were scanned in supine position with a dual-source 128-