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TECHNICAL NOTE

GENERAL; PATHOLOGY/BIOLOGY

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Whole Body Postmortem Magnetic Resonance Angiography

ABSTRACT: Computed tomography (CT) and magnetic resonance (MR) imaging have become important elements of forensic radiology. Whereas the feasibility and potential of CT angiography have long been explored, postmortem MR angiography (PMMRA) has so far been neglected. We tested the feasibility of PMMRA on four adult human cadavers. Technical quality of PMMRA was assessed relative to postmortem CT angiography (PMCTA), separately for each body region. Intra-aortic contrast volumes were calculated on PMCTA and PMMRA with segmentation software. The results showed that technical quality of PMMRA images was equal to PMCTA in 4/4 cases for the head, the heart, and the chest, and in 3/4 cases for the abdomen, and the pelvis. There was a mean decrease in intra-aortic contrast volume from PMCTA to PMMRA of 46%. PMMRA is technically feasible and allows combining the soft tissue detail provided by MR and the information afforded by angiography.

KEYWORDS: forensic science, forensic radiology, postmortem radiology, postmortem magnetic resonance imaging, vascular imaging, angiography, postmortem MR angiography

Over the last decade, computed tomography (CT) and magnetic resonance (MR) imaging have been introduced to forensic radiology and the field has evolved significantly (1–4). The development of postmortem CT angiography (PMCTA) made postmortem imaging more robust, particularly in regard to vascular pathology and solid organ laceration (5–9). MR provides more detailed soft tissue information than CT, and the use of postmortem MR has increased in recent years (10–15). A combination of the soft tissue detail provided by MR and the information afforded by angiography would be very useful. It was the goal of this study to assess the feasibility of postmortem MR angiography (PMMRA) and to evaluate technical image quality compared with PMCTA.

Materials and Methods

Subjects

The responsible justice department and the ethics committee of the local university both approved this study. PMMRA was tested on five human cadavers, delivered to our institute for forensic evaluation (i.e., external inspection and postmortem imaging). One case was excluded from the study population. Exclusion criterion was relevant iatrogenic arterio-venous fistula caused by a technician taking a blood sample from the femoral vein before, instead of during the vessel cannulation for angiography. Because of the fistula, arterial contrast leaked into the venous system and both the PMCTA and PMMRA failed technically. The final study population consisted of four human cadavers: three men and one woman, mean age at the time of death: 72 years, range: 58–83 years, median 74 years).

Imaging Protocols

PMCT imaging of the head, thorax, abdomen and pelvis was performed using a helical, multi-detector CT scanner (Somatom Emotion 6; Siemens, Forchheim, Germany) with raw data acquisition at 110 kVp, 160 mAs, and 6×1 mm collimation. CT image reconstruction was performed with a slice thickness of 1.25 mm in increments of 0.7 mm, using soft tissue, and bone-weighted tissue kernels. PMMR imaging was performed using a 1.5-Tesla MR scanner, equipped with a total-imaging-matrix (TIM) coil system (Magnetom Symphony; Siemens, Erlangen, Germany). Standard sequences were coronal whole body TIM T1-weighted (T1W) and inversion recovery (STIR) sequences with a slice thickness of 5 mm; axial images of the head, thorax, abdomen, and pelvis consisting of T1W, T1W with fat saturation (T1WFS), and T2-weighted (T2W) sequences, all with a slice thickness of 5 mm. Noncontrast PMCT and PMMR were performed in each case before PMCTA and PMMRA using the same imaging protocols. PMCT scan time was <15 min (including tube cooling time) for each scan series. PMMR scan time was *c.* 100 min. All scans were performed in the supine position.

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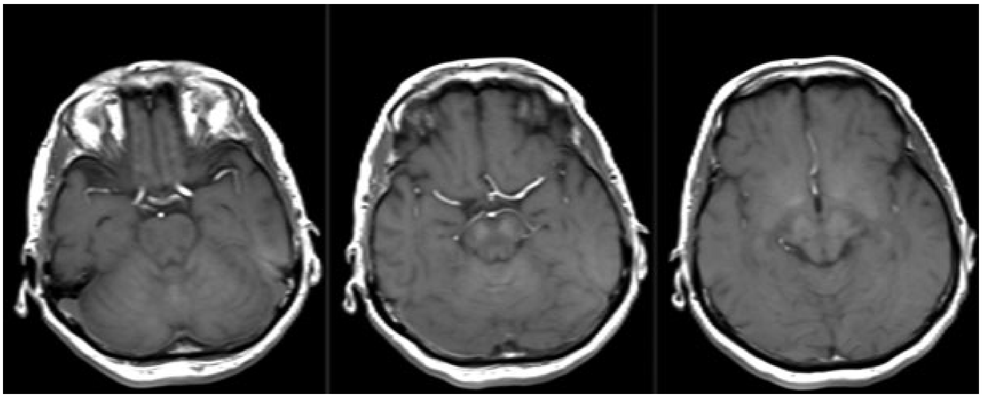

FIG. 1—*Axial T1W postmortem MR angiography images of the head at multiple levels demonstrate complete filling of all vessels of interest. Subjectively, adequacy of this angiographic exam approaches that of clinical angiography.*

Protocols for Postmortem Angiography

Vascular access was gained via the femoral vessels, using a unilateral vascular cut-down. We used a hydrophilic iodinated contrast medium (Optiray 300; Guerbet, Zürich, Switzerland) diluted in a solution of polyethylene glycol (PEG) (PEG 200; Schärer und Schläpfer AG, Rothrist, Switzerland) to a ratio of 1:13.3 (75 mL contrast medium to 1000 mL PEG). A total volume of 1500 mL was injected in the arterial system of each corpse with a roller pump (HL 20; Maquet Cardiopulmonary AG, Hirrlingen, Germany) at a flow rate of *c.* 20 mL/sec. The time needed for each vascular cut-down and tube placement was about 45 min. PMCTA was performed immediately after completion of the vascular injection. For PMMRA, the femoral cannulae were disconnected from the roller pump and sealed, and each corpse was immediately moved to the adjacent MR suite for PMMRA. PEG-diluted contrast medium proved to be hyperintense in T1W-images and hypointense in T2W-images in preliminary MR tests. No gadolinium was used for PMMRA.

Image Interpretation

Images were reviewed simultaneously by two radiologists (4 and 9 years experience), using a picture archiving and communication system workstation (IDS7; Sectra AB, Linköping, Sweden). The regions (and vessels) of interest included the major vessels of the head (vertebral arteries and carotids, the basilar artery, and the anterior, middle, and posterior cerebral arteries), chest (thoracic aorta and arch vessels), heart (coronary arteries), abdomen (abdominal aorta, celiac axis, and common hepatic, splenic, superior mesenteric, and inferior mesenteric arteries), and pelvis (common, external, and internal iliac arteries).

Technical Quality of PMMRA

The technical quality of PMMRA was assessed objectively for each vessel of interest as being equal or inferior to PMCTA based on the degree of vessel filling by contrast and visualization of the vascular bed. Conclusions were arrived at by consensus.

Calculation of Intravascular Contrast Volume

We used dedicated segmentation software (AMIRA, version 5.2.2; Visage Imaging, Berlin, Germany) to calculate the intra-aortic contrast volume (from the posterior margin of the left subclavian artery origin, to the aortic bifurcation) on both PMCTA and PMMRA.

Results and Discussion

Results

In the head (Fig. 1), the chest (Fig. 2), and the heart technical quality of PMMRA was equal to PMCTA in all 4/4 subjects. In the abdomen (Fig. 3), the technical quality of PMMRA was equal to PMCTA in 3/4 subjects. In one case (case 3), technical quality

FIG. 2—*Coronal TIM postmortem MR angiography: noncontrast T1W (a) and postcontrast T1W (b). Note hyperintense contrast in the left ventricle, ascending aorta, and aortic arch vessels on (b). The artifact overlying the left femoral triangle on both (a) and (b) is secondary to the integral metallic stiffeners of the vascular cannulae.*

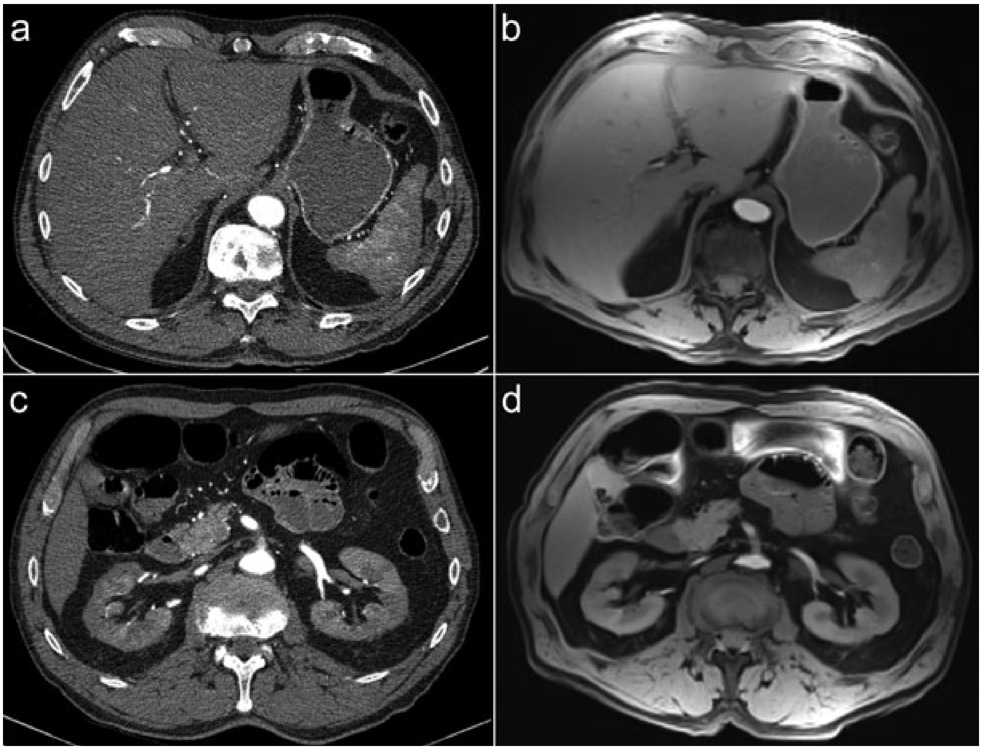

FIG. 3—*Corresponding axial postmortem CT angiography (PMCTA) (a) and (c) and T1WFS postmortem MR angiography (PMMRA) (b) and (d) of the abdomen at the levels of the diaphragmatic hiatus (a) and (b) and the celiac trunk (c) and (d). Abdominal vessels are filled with contrast and both, PMCTA and PMMRA were rated adequate. Note the decreased volume of aortic contrast in the PMMRA image (d), compared to the PMCTA image (c).*

TABLE 1—*Summary of diagnostic quality of postmortem MR angiography (PMMRA) relative to postmortem CT angiography (PMCTA).*

Region	Case 1	Case 2	Case 3	Case 4	Total =	Total <
Head	=	=	=	=	4/4	0/4
Chest	=	=	=	=	4/4	0/4
Heart	=	=	=	=	4/4	0/4
Abdomen	=	=	<	=	3/4	1/4
Pelvis	=	=	<	=	3/4	1/4
Total =	5/5	5/5	3/5	5/5		
Total <	0/5	0/5	2/5	0/5		

=, technical quality of PMMRA equal to PMCTA.
<, technical quality of PMMRA inferior to PMCTA.

TABLE 2—*Aortic volume measurement and overview of vascular pathologies.*

Case No.	CTA (mL)	MRA (mL)	Loss (%)	Over Time (min)	Vascular Pathology
Case 1	90	54	−39	17	Ruptured AA
Case 2	154	68	−56	33	Occlusion of the left ICA
Case 3	174	77	−56	26	Ruptured AA
Case 4	198	130	−35	43	None
Mean	154	82	−46	30	
Median	164	73	−47	30	

AA, ascending aortic aneurism; ICA, internal carotid artery.

of PMMRA was inferior to PMCTA, with no filling of the splenic artery and the distal aorta. In the pelvis, the technical quality of PMMRA was also equal to PMCTA in 3/4 subjects. In one case (case 3), there was no contrast in the pelvic vessels with the exception of the right external and internal iliac artery. An artifact from a metallic component in the vascular cannulae partially obscured visualization of the cannulated vessels on PMMRA in all the four cases. Table 1 summarizes the results on technical quality. There was mean loss of 46% of intra-aortic contrast volume from PMCTA (mean volume: 154 mL) to PMMRA (mean volume: 82 mL). The mean time interval between image acquisition for PMCTA and PMMRA was 30 min (Table 2).

Discussion

This preliminary technical study demonstrates the feasibility of whole body PMMRA based on methods developed and tested for PMCTA (5–8). Technical quality of PMMRA was equal to PMCTA the majority of the evaluated vessels. PMMRA of the head and the chest showed the best results. Satisfactory PMMRA results have also been achieved in the abdomen, although overall, the abdominal vessels were not depicted as well as vessels in the head and chest. Pelvic arteries were more problematic because of metallic artifact from the vascular cannulae obscuring iliac vessels on the side of the vascular access. The cannulae should therefore contain as little ferromagnetic components as possible. Aside from the cannulae, there is no need for MR-safe equipment because both the vascular cut down and the contrast injection can be performed before a corpse is transported to the MR suite. The loss of intravascular contrast volume on PMMRA compared with PMCTA was most prominent in nondependent vessels. This is probably related to gradual gravity dependent settling of fluids (16,17) and suggests that both the time between contrast infusion and imaging and scan times should be minimized. In our study, the scan times were 15 min for PMCTA and 100 min for PMMRA. Our findings regarding incomplete filling of nondependent vessels concur with

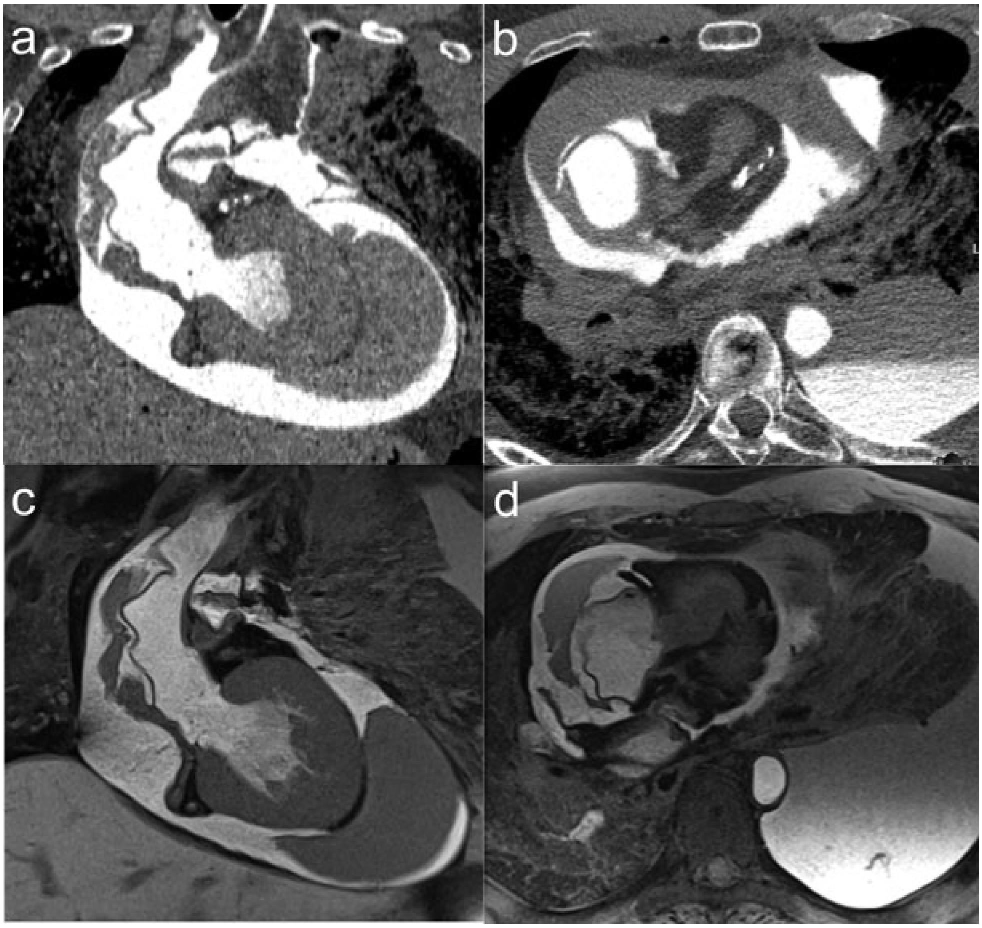

FIG. 4—*Corresponding coronal (a) and axial (b) postmortem CT angiography and coronal (c) and axial (d) T1WFS postmortem MR angiography. Image (a) was reconstructed from axial CT images using multiplanar reformatting; image (c) is a detailed view from the coronal whole body T1WFS TIM scan. Both modalities clearly display a ruptured aneurysm of the ascending aorta with contrast extravasation into the pericardium and the left hemithorax.*

the data of other studies (8). Better vascular distension and intravascular contrast volumes on PMMRA might be obtained by reducing the number of MR sequences or focusing MR on a single body region. Both approaches would decrease the time interval between contrast instillation and MR image acquisition and therefore limit the degree of contrast sedimentation or leakage. However, PMCTA will always be faster than PMMRA and provides excellent visualization of vascular pathologies (5–8). Overall, MR is more expensive, more complex, and more time consuming than CT. Nevertheless, in difficult cases, or when minimally invasive autopsy is performed in lieu of a traditional autopsy, the combination of the soft tissue detail and information regarding vascular pathologies provided by PMMRA will be worth the price. It should be noted that the absence of circulation in the postmortem setting precludes the use of dynamic clinical MRA sequences such as time of flight imaging and the maximum intensity projections. Although not the focus of this technical note, all vascular pathology identified at PMCTA was also seen at PMMRA (Figs 4 and 5).

Limitations

Several limitations of the study deserve mentioning: First, the study is limited by the small, heterogeneous sample population. However, this study was performed to assess the technical feasibility. Additional studies are needed to assess utility and indication for PMMRA in forensic radiology. Second, image findings were not correlated with autopsy but with CT angiography only. Although radio-pathologic correlation is of paramount importance to forensic radiology, in this study we exclusively assessed the feasibility of PMMRA and technical image quality compared with CT angiography. The validation of the pathologic findings was not the goal of the study. Third, MR angiography was performed without the use of gadolinium as contrast medium. However, gadolinium is very expensive and the mixture of iodinated contrast and PEG proved to be an effective contrast medium for PMMRA on preliminary tests and caused no MR artifacts in adjacent, nonvascular structures. Additionally, gadolinium has neither been evaluated with regard to edema and undesirable facial swelling due to increased capillary permeability in the deceased (18), nor has the appropriate volume of gadolinium for postmortem angiography been assessed (19).

Conclusions

This study demonstrates the technical feasibility of whole body MR angiography in the postmortem setting. PMMRA images can be generated with a cost-effective contrast mixture, using a straightforward technique, and virtually without the need for MR safe equipment. PMMRA combines the soft tissue detail provided by MR and the information afforded by angiography. This technique

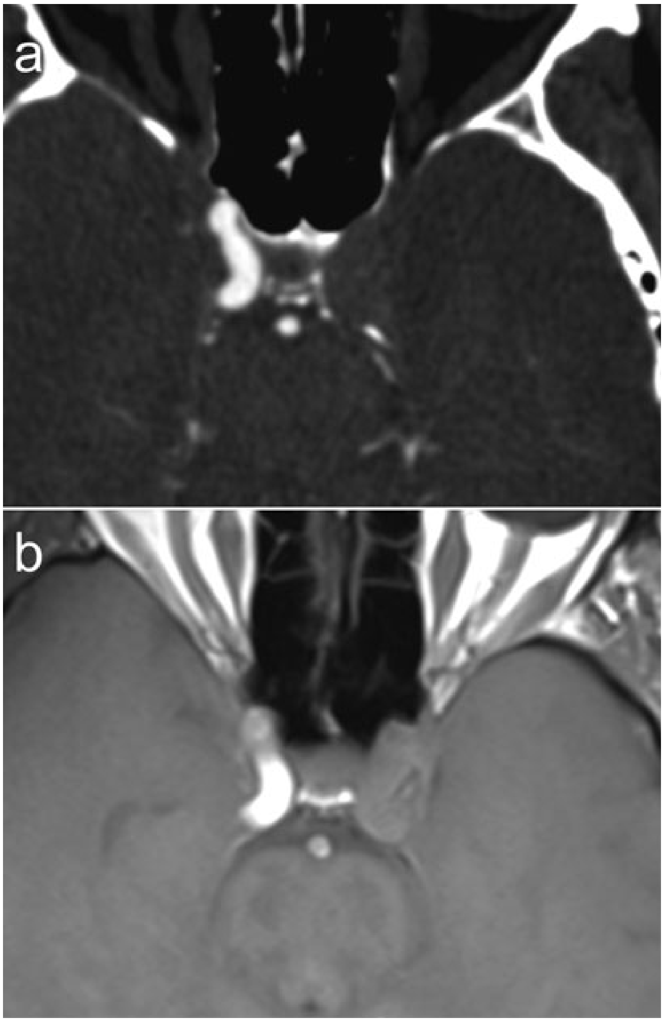

FIG. 5—*Axial postmortem CT angiography (a) and axial T1W postmortem MR angiography (b). Both modalities clearly depict an occlusion of the intracranial portion of the left internal carotid artery.*

may extend the radiological tools available for postmortem investigations, whether they are performed in the course of forensic investigation, or during hospital-based morbidity/mortality review.

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