

## Detection of reperfused pulmonary arteriovenous malformations with contrast-enhanced magnetic resonance angiography

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**Purpose:** To evaluate the potential of contrast-enhanced magnetic resonance angiography (CE-MRA) for detection of reperfused pulmonary arteriovenous malformations (PAVMs) after catheter embolization in patients with hereditary hemorrhagic telangiectasia (HHT).

**Materials and Methods:** Between February 1999 and October 2007 230 patients with diagnosed HHT (according to established Curaçao criteria), or first degree relatives, underwent MRI screening for cerebral, pulmonary and visceral manifestations of HHT. The database was retrospectively analyzed for patients with reperfused PAVMs following catheter embolotherapy. The diagnosis of reperfused PAVM was made based on contrast-enhanced MRA and confirmed by catheter angiography. CE-MRA was performed using a three-dimensional gradient-echo sequence (TR: 4.6 ms, TE: 1.8 ms, FA: 30°, matrix: 160-180×512, FOV: 320×450-500 mm [coronal], slab thickness: 120-160 mm, reconstructed slice thickness: 1.8-2.2 mm) with asymmetric k-space acquisition in which the center of k-space was acquired during the first third of the sequence. The contrast agent utilized was gadobenate dimeglumine, administered at a single dose of 0.1 mmol/kg bodyweight.

**Results:** During the observation period 40 patients with one or multiple PAVMs (104 PAVMs in total) underwent catheter embolization using Nester<sup>®</sup> platinum coils. In each case complete occlusion of the feeding vessels was achieved. Follow-up CE-MRA studies performed at 3 and 12 months after initial embolization revealed reperfusion of 5/104 embolized PAVMs in 4 of these 40 patients. Additionally, CE-MRA revealed 6 reperfused PAVMs in 3 patients who underwent embolization elsewhere. All patients with reperfused PAVMs underwent catheter angiography of the pulmonary vasculature and re-embolization of the reperfused PAVMs. No additional reperfused PAVMs were detected on catheter angiography. Due to overlying embolization materials CE-MRA was helpful for the re-embolization procedure especially in the case of complex PAVMs to define the reperfused vessels (Fig. 1 a, b). Reperfusion of the 5 PAVMs in the 4 patients treated at our center was due to biodegradation of coils (2 reperfused PAVMs in 1 patient) caused by corrosion of applied tungsten filaments which are no longer used in our institution; insufficiently tight packing of the embolization coils (1 PAVM in 1 patient) noted at one year follow-up; and opening of collateral feeding vessels (2 PAVMs in 2 patients) which was not present during screening CE-MRA, initial embolotherapy or post-embolization CE-MRA performed at 3 months after therapy. Of the 3 patients initially embolized at other centers reperfusion of 6 PAVMs was caused by insufficient packing of the embolization material. During re-embolization, 1 patient demonstrated clinically insignificant cerebellar ischemia on DWI imaging post embolization, although no other complications were noted.

**Conclusion:** As a minimally-invasive therapy, successful catheter embolization of PAVMs in patients with HHT heavily depends on compact packing of the platinum coils to generate a sufficient and durable occlusion. However, whereas initial imaging studies may show complete obliteration of feeding vessels, reperfusion may occur after a longer time interval. Furthermore opening of small collateral vessels may also result in reperfusion of treated PAVMs. Thus, there is a strong need for regular follow-up examinations. At many centers CT imaging is often used for this purpose, despite the fact that image quality and the ability to accurately detect PAVM reperfusion may be affected by metal artifacts arising from the embolization material used. Our results show that CE-MRA is a useful alternative tool for follow-up of treated PAVMs.

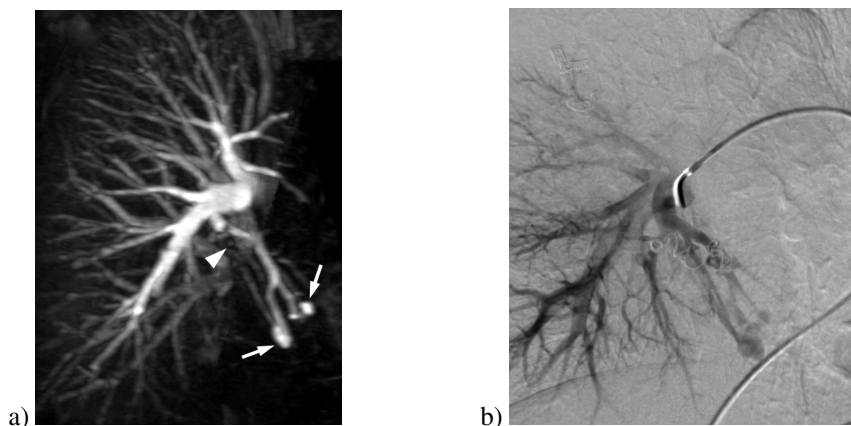


Fig. 1: CE-MRA (a) and corresponding catheter angiography (b) of a patient with reperfused PAVMs (arrows in a). Note the good correlation between MRA and catheter angiography, although in this patient who was treated elsewhere with steel macrocoils an area of metal artefact (arrowhead in a) can be noted.