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Categorization of aortic aneurysm thrombus morphology by magnetic resonance imaging

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ABSTRACT

Background: Magnetic resonance imaging (MRI) has been proposed for qualitative categorization of intraluminal thrombus morphology. We aimed to correlate the qualitative MRI categorization previously described to quantitative measurements of signal intensity and to compare morphological characteristics of intraluminal thrombus specimens to the appearance on magnetic resonance imaging.
Methods: Thirty-four patients undergoing open surgery for abdominal aortic aneurysm had a preoperative MRI obtained with a 1.5 T magnet. Qualitative categorization was performed (blinded and in consensus) and correlated to intraluminal thrombus to muscle signal-intensity ratios. Morphology of intraluminal thrombus specimens collected during surgery were compared to the magnetic resonance imaging categories and specimen weight was correlated to thrombus volume measured on preoperative computer tomography angiography.
Results: Blinded MRI categorization resulted in agreement in 22 out of 34 intraluminal thrombi (Kappa value 0.3, $p = 0.006$). Medians ($p = 0.004$) and distribution ($p = 0.002$) of signal-intensity ratios varied significantly across the three MRI categories obtained by consensus. Heterogeneous and homogenous specimen appearance corresponded to similar appearances on MRI in 78% and 55% respectively, resulting in an overall Kappa = 0.4 ($p = 0.04$). Intraluminal thrombus volume and weight correlated well (r_s 0.831, $p < 0.001$) with a mean difference of 60 g (95% CI 38–80 g), without proportional bias.
Conclusion: Qualitative evaluation of intraluminal thrombus morphology based on MRI can be quantified by measuring signal-intensity ratios. Concurrently a fair agreement to blinded qualitative evaluation of thrombus specimens can be obtained. However, the evaluation is impaired by loss of a large proportion of thrombus during sampling.

1. Introduction

Abdominal aortic aneurysm (AAA) represents a potentially life-threatening condition seen in 5–10% of men above the age of 65 years [1]. Aneurysms expand over time and when they reach a diameter >6 cm the annual risk of rupture is estimated to 10–20% [2]. Mortality related to aneurysm rupture is 85% and therefore preventive repair is recommended when the aneurysm reaches 5.5 cm [2]. The natural history of AAA is uncertain and preventive intervention is considered a high-risk procedure although endovascular aortic repair (EVAR) has decreased 30-day risk of morbidity and mortality as compared to open surgery [3–5].

The vast majority of AAAs is lined by an intraluminal thrombus (ILT) [6]. The ILT is a biologically active entity penetrated by a continuous network of canaliculi through which macromolecules such as metalloproteinases can reach the aneurysm wall [7–10]. The aneurysm wall is thinner and contain less elastin in thrombus covered areas than in areas without thrombus [11–13] and there is evidence that the ILT participates in aneurysm growth [14,15]. High attenuation within the ILT on non-enhanced computed tomography (CT) is correlated with bleeding in the ILT and

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this so-called crescent sign is suggested to signal impeding rupture of the aneurysm sac [16,17]. Assuming that the ILT plays a role in growth and rupture the introduction of endovascular aneurysm repair has added an extra dimension to the significance of the ILT. It has been speculated that biological mediators in the ILT may play a part in the post implantation syndrome [18] and that continued modulation of the aneurysm wall mediated by the ILT leads to late aneurysm related complications after EVAR [19].

Predicting the risk of rupture for the individual patient is difficult solely based on AAA size and growth rate [20], however, diameter is still considered the gold standard for predicting risk of rupture [21]. The ILT has been speculated to be a potential predictor of the prognosis [22]. So far primarily biomechanical studies of ILT effect on peak wall stress [23,24] and pressure [25,26] have been conducted – and the reported results are conflicting.

The diversity in ILT morphology potentially represents functional characteristics of the thrombi with different potential for contributing to the post implantation syndrome. Magnetic resonance imaging (MRI) offers a significant advantage to CT considering the morphological appearance of ILT [22]. Only few studies on MRI characterization of AAA intraluminal thrombus morphology exist. Castrucci et al., [27] performed a study on 45 AAA patients with ILT > 1 cm thick on sonography. They performed non-blinded evaluation of macroscopic ILT morphology by consensus on MRI and operatively collected thrombi obtaining 100% agreement. The qualitative MRI categorization was based on signal intensity (SI) and the specimen categorization on degree of ILT organization [27]. Kramer et al., [28] identified fibrous cap, thrombus and lipid components of the plaque within AAA by T2 weighted MRI and Nchimi et al., [29] have correlated the histological morphology of ILT specimens with MRI and visualized leucocyte phagocytic activities in the ILT by SPIO (superparamagnetic iron oxide) uptake.

We aimed to correlate the qualitative MRI categorization described by Castrucci et al., [27] to quantitative measurements of signal intensity and to compare morphological characteristics of ILT to MRI appearance.

2. Materials and methods

2.1. Patients

Consenting patients planned for elective treatment of AAA by open surgery at our University hospital were eligible for inclusion. Exclusion criteria comprised (1) Positive HIV, Hepatitis B or C status (2) Immuno-inflammatory disease – except topically treated skin disease and respiratory disease (3) Immunosuppressive treatment (4) Current treatment for cancer (5) Alcohol consumption: Men > 36 g/day and women > 24 g/day respectively (6) MRI incompatible implants or foreign bodies (7) Claustrophobia (8) Intraluminal thrombus thickness <1 cm on preoperative CTA (9) Allergy towards the MRI contrast agent Gadobutrol (10) Pregnancy. The first five exclusion criteria were implemented to avoid confounding by acute inflammatory activity or suppression.

Fifty-eight AAA patients were screened, 37 patients were included but three patients did not complete the protocol leaving 34 patients for analysis according to Fig. 1 (four women, 30 men; median age 72.5 years (Inter Quartile Range (IQR) 68–76.3 years); median AAA diameter 6.7 cm (IQR 5.8–7.3 cm)).

The study was registered with the National Data Protection Agency ref. no. 2007-58-0015 30-0384 and approved by the National Committee on Biomedical Research Ethics, approval no. H-A-2009-044. Participating patients gave written informed consent and the study was conducted in accordance with the principles stated in the Declaration of Helsinki.

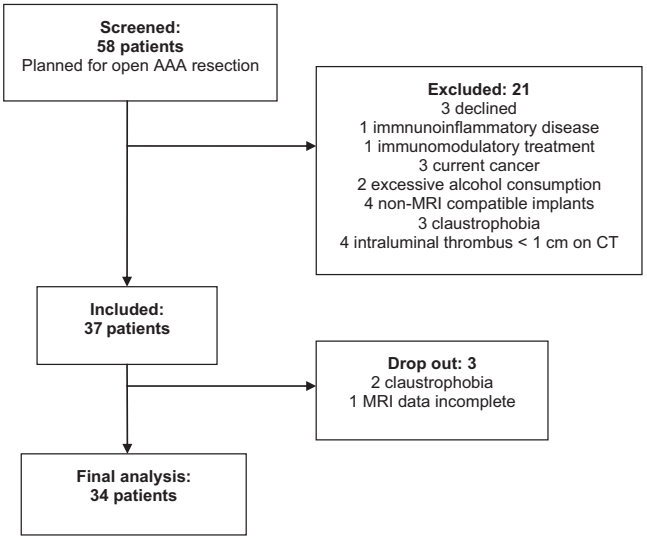

Fig. 1. Flowchart for patient inclusion.

2.2. Biological specimens

Intraluminal thrombi were collected during surgery, anatomic orientation secured, the ILT as a whole was weighed, sliced in approximately 1 cm axial slices and photographed. One representative thrombus slice was chosen for comparisons.

2.3. Imaging

Preoperative biphasic acquisition CTA was performed in house using a helical 64-slice CT scanner (Toshiba Medical Systems Ltd., Crawley, The United Kingdom). Detector configuration was 0.5 × 64 (collimation = 32 mm) with a pitch of 0.8. A bolus dose of 80 ml non-ionic iodinated contrast medium (Iohexol 350 mg/ml, Omnipague®; GE Healthcare Denmark A/S, Copenhagen, Denmark) was injected into an ante-cubital vein at a rate of 3 ml/sec. Scan reconstructions with a slice thickness and increment of 1–3 mm. Preoperative CTA were also accepted from referring centres performed on other CTA vendors but scanned in a similar mode.

An experienced radiologist assessed the 2-D CT diameter of the aorta. The maximal diameter was measured from outer to outer circumferential wall using a PACS system (Agfa Impax 5.2, Agfa-Gevaert NV, Mortsel, Belgium) allowing assessment in both the native axial CT slices and in the multiplanar reconstructions (sagittal and coronal plane).

Preoperative MRI of the abdominal aorta was performed on a Siemens AVANTO 1.5 T (Siemens Medical Systems, Germany) scanner with a standard body coil placed around the abdomen and conventional prospective ECG triggering. After scout imaging (in axial and coronal planes) a segmented T1 weighted spoiled gradient echo sequence with breath-hold was performed. Then we performed a multi slice T1 weighted turbo spin echo sequence without breath-hold (TR: 858.1 ms, TE: 15 ms, turbo factor: 3, acquisition matrix of 166 × 256 pixels, FOV: 260 mm × 320 mm, slice thickness: 6 mm, pixel spacing: 1.25 mm) and afterwards T2 weighted turbo spin echo single slices images with breath-hold (TR: 1813.8 ms, TE: 84 ms, turbo factor: 23, acquisition matrix of 166 × 256 pixels, FOV: 276 × 340 mm, slice thickness: 5 mm, pixel spacing: 1.33 mm) were obtained. Finally the T1-weighted turbo spin echo multi slice sequence was repeated approximately 5 min after contrast infusion (Gadobutrol 0.1 ml/kg) with identical parameters as before contrast.