Dynamic CE-MRA for Endoleak Classification after Endovascular Aneurysm Repair

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Aim. To evaluate the value of dynamic contrast enhanced magnetic resonance angiography (CE-MRA) for classification of endoleaks after endovascular aneurysm repair (EVAR).

Materials and methods. Twenty-eight patients, between 2 days and 54 months after EVAR, were evaluated with CTA, MRI and dynamic CE-MRA. The additional diagnostic value of the dynamic 3D CE-MRA was evaluated by determining the ability of the dynamic series in pinpointing the site of inflow of an endoleak.

Results. An endoleak was detected in 23 patients. Seventeen of the 23 dynamic series were technically successful (no disturbing artifacts limiting the diagnostic value). Using MRI our findings were: 2 type I, 6 type II, 1 type III, no type IV endoleaks and in 14 cases classification could not be made. The classification results for MRI plus the dynamic CE-MRA were: 2 type I, 12 type II, 1 type III, no type IV endoleaks and in eight cases classification could not be made. In six cases the dynamic MRA allowed classification of the endoleak, which was not possible with the non-dynamic images alone (p = 0.091, Fisher exact).

Conclusion. This pilot study shows that dynamic CE-MRA can have additional value in the classification of endoleaks. Dynamic CE-MRA might obviate the need for diagnostic digital subtraction angiography and aid planning for intervention.

Keywords: Abdominal aortic aneurysm; Endovascular; MRI; Diagnostic imaging; Endoleak.

Background

Determining the effectiveness of exclusion after endovascular aneurysm repair (EVAR) is essential for the evaluation of treatment success and follow-up. The absence or presence of endoleaks is therefore important in every assessment.1-4 If an endoleak is detected on computed tomography angiography (CTA), a decision must be made whether or not to intervene. If the CTA assessment provides insufficient information of the site of inflow or outflow of the endoleak, most centers will use digital subtraction angiography (DSA) to pinpoint the exact site of inflow in order to plan an intervention to seal the endoleak.2,5-7 It can be difficult to depict type II endoleaks and even small type I endoleaks using this technique.8,9 An experienced interventional radiologist can be more successful using super selective DSA.8,10-13 DSA has the inherent disadvantages of its invasive character, the contrast medium and radiation load to the patient, and a small but significant morbidity and mortality.14-16

MRI and magnetic resonance angiography (MRA) techniques, with their excellent soft tissue contrast, lack of ionizing radiation and nephrotoxic contrast agent form an interesting alternative to regular CTA based follow-up. Moreover, recent developments in MRI hardware and software, like the implementation of SENSE (parallel imaging) and ultra fast gradient systems have made fast dynamic scanning in 3D (also called 4D scanning) possible. The time resolved 3D MRA dataset is constructed out of sequential 3D volumes and provides information about the contrast dynamics without the need for invasive catheterization.

It has previously been demonstrated that MRI and MRA are more sensitive to endoleak detection than CTA.17,18 We hypothesized that adding a time-resolved MRA series to our standard non-dynamic MRI-protocol for follow-up after EVAR would improve endoleak classification. In order to investigate whether this hypothesis holds true, a dynamic contrast
enhanced (CE) MRA scan was added to our standardized MRI scan protocol. The standard CTA surveillance protocol, the standard MRI surveillance protocol and CE dynamic MRA were compared. Differences in pinpointing the exact sites of inflow and the additional value of having information about the filling phase for classifying endoleaks were evaluated.

Patients and Methods

Patients

In the period between March 2001 and March 2003, 28 patients randomly selected were included in the study. This group consisted of 26 males and two females with a mean age of 75 years (range 58–87), treated by Excluder (n=3, Gore, Flagstaff, AZ, USA) or Ancure endografts (n=25, EVT, Menlo Park, CA, USA), who were imaged using CTA, MRI and dynamic CE-MRA. Five patients were evaluated twice and one patient three times resulting in 35 MRI and CTA data sets. Institutional review board approval was obtained and all included patients signed an informed consent form. Patients were between 2 days and 65 month (mean 30 months) after EVAR at the time of examination. The time between the CT and the MR exam was minimized and was not allowed to exceed 1 month.

Design

The MRI scans and the CTA scans were evaluated for the presence of endoleaks and for endoleak classification. Endoleak was scored as present, not present or uncertain. Classification of the endoleaks was performed as proposed by White et al.: type I (leakage at the attachment site), II (retrograde filling via branch arteries), III (leakage due to a graft defect), IV (leakage due to graft wall porosity) or unknown.7,19 The images were evaluated by an experienced observer blinded to the results of the other imaging modality. The data were evaluated on a separate graphical workstation (Easy Vision, Philips Medical Systems, Best, The Netherlands).

Clinical data acquisition techniques

Computed tomography angiography: CT scans were performed on a spiral CT scanner (AV-EP, Philips medical systems, Best, The Netherlands). The table speed used was 5 mm/s with a reconstruction index of 2 mm and a pitch of 0.25. One non-contrast-enhanced scan and one with an intravenous infusion of 140 ml Ultravist at 3 ml/s with a 30 s delay between the start of the injection and the start of the scan were acquired at 120 kV and 250 mA with a matrix size of 250. In order to reduce the radiation dose for the patients, delayed CT series (2 scans with 2 and 4 min interval after the CTA) were only performed in case an endoleak was suspected, i.e. in case of a growing or stable non-luminal volume of the aneurysm sac based upon previous assessments.20

Magnetic resonance imaging and angiography: MRI scans were performed on a clinical 1.5-T scanner (Gyroscan Intera NT, Philips Medical Systems, Best, The Netherlands). A quadrature wrap-around synergy body coil was used as a receive coil. The following scans out of our MRI-protocol for follow-up after EVAR were used for this study:

1. Pre-contrast T1-weighted spin echo: TR/TE/α = 580 ms/14 ms/90°, slice thickness 6.0 mm, 30 slices, FOV 270×385 mm², acquisition matrix 179×256. Total acquisition time: 2.30 s.

2. Coronal dynamic 3D contrast enhanced (CE)-MRA using SENSE factor 2 (approximately 6.5 s per volume): TR/TE/α = 4.0 ms/1.3 ms/50°, slice thickness 4.0 mm interpolated to 2 mm slices, 28 slices, FOV 360×450 mm², Matrix 154×256. Ten dynamic volumes with breath hold technique for as long as the patient could hold his/her breath. Twenty milliliters of Gd-DTPA contrast agent (Magnevist, Schering, Berlin, Germany) was administered intravenously at 2.0 ml/s, followed by a saline chaser bolus of 20 ml injected at 1.5 ml/s. The injection of the contrast agent was started together with the acquisition of the dynamic series.

3. Coronal 3D CE-MRA: TR/TE/α = 8.5 ms/2.1 ms/45°, slice thickness 3.0 mm interpolated to 1.5 mm slices, 35 slices, FOV 360×450 mm², Matrix 154×512. Total acquisition time was 28 s with the breath hold technique. Twenty millilitres of contrast agent was injected intravenously at 2.0 ml/s, followed by a saline chaser bolus of 20 ml at 1.5 ml/s.

4. Post-contrast T1-weighted spin echo (as pre-contrast).

In the complete MRI scan protocol, 40 ml of Gd-DTPA was administered intravenously. The MRI images were made anonymous and evaluated by an experienced observer. A comparison of the pre-contrast and post-contrast T1-weighted spin echo...
scan was used for endoleak detection. The 3D CE-MRA scan was used for endoleak classification. First both T1-weighted spin echo scans and the 3D CE-MRA were assessed. In a second evaluation the dynamic CE-MRA was added to the data available to the observer. Differences between the detection and classification of endoleaks with and without the dynamic scan were noted. During the second evaluation the observer was blinded to the results of the first evaluation. Dynamic scans were considered technically unsuccessful if diagnostic evaluation was seriously compromised by patient motion, fold-over artifacts or inadequate planning, and the observer was asked to report unsuccessful scans.

**Image analysis**

All scans were loaded onto the graphical workstation. Analysis of the CTA images involved: A comparative stack view of the unenhanced CT and the enhanced CTA, and multi planar reconstructions (MPR) and central lumen line (CLL) reconstructions of the contrast enhanced scan. Analysis of the MRI and MRA images involved: A comparative stack view of the unenhanced T1-weighted scan and the T1-weighted scan after contrast enhancement, an evaluation of maximum intensity projections (MIP) of the CE-MRA, a MPR and CLL reconstructions of the CE-MRA and T1-weighted scan after contrast enhancement, a 3D evaluation of the (MIP) of the dynamic series and an evaluation of the individual slices of the dynamic series.

**Statistical analysis**

For statistical analysis of the difference in endoleak classification a Fisher exact test was used. A $p$-value of less than 0.05 was considered significant.

**Results**

In the evaluation of the 35 CTA data sets 11 endoleaks (31%) were identified in 11 patients. In five cases classification of the detected endoleak was not possible. Using MRI 23 (65%) endoleaks were detected in 35 MRI examinations by comparison of T1-weighted pre- and post-contrast scans. An example is shown

![Fig. 1. A comparison of a slice of a T1-weighted pre- and post-contrast scan at exactly the same location in the patient, demonstrating an endoleak.](image1)

![Fig. 2. An example of a MIP of a 3D CE-MRA scan. The arrow is pointing at a clearly visible type II endoleak filling the aneurysm sac.](image2)
in Figs. 1 and 2. All endoleaks identified with use of CTA were identified on MRI evaluation. In 17 of the 23 cases with an endoleak, the dynamic MRA scan was technically successful (69%). Four scans were unsuccessful due to inadequate scan planning and two were unsuccessful due to movement of the patient.

In six cases the addition of the dynamic CE-MRA scan allowed classification of the endoleak, which was not possible with use of the non-dynamic scans only (Fig. 3). The overall classification results for our standard protocol without the dynamic CE-MRA were: 2 type I, 6 type II, 1 type III, no type IV endoleaks and in 14 cases classification could not be made. The classification results for our standard protocol plus the dynamic CE-MRA were: 2 type I, 12 type II, 1 type II, no type IV endoleaks and in eight cases classification could not be made (Table 1; p = 0.091, Fisher exact). All type I and type III endoleaks could be depicted with use of the dynamic CE-MRA. Relatively small endoleaks could not be depicted using the dynamic series.

**Discussion**

MRI evaluation after EVAR is more sensitive to endoleak detection than CTA.\(^{18,21–23}\) The addition of time-resolved or dynamic series to the standard MRI/MRA protocol can aid in the determination of the location of inflow of an endoleak. The dynamic scan though, can only be used in combination with the other scans due to the moderate resolution, which is a result of the added temporal resolution. The non-dynamic MRA and the post CE T1-weighted MRI must direct the observer to the site of interest. A practical problem is that the dynamic scan results in an excessive amount of data, which makes it difficult to interpret and requires a powerful graphical

![Fig. 3. An example of the MIP of a dynamic 3D CE-MRA scan (the same patient as in Fig. 2). Every image is the MIP of a 3D volume out of the 4D dataset in which the volumes were acquired 6.2 s after each other. The contrast arrival, dispersion and outflow are visualized. The arrow points at a small type II endoleak.](image)

![Fig. 4. An example of the MIP of a dynamic 3D CE-MRA scan (the same patient as in Fig. 2). Every image is the MIP of a 3D volume out of the 4D dataset in which the volumes were acquired 6.2 s after each other. The contrast arrival, dispersion and outflow are visualized. The arrow points at a small type II endoleak.](image)

<table>
<thead>
<tr>
<th>Number of endoleaks detected</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Unknown type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard CTA protocol</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Standard MRI protocol</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>Standard protocol plus dynamic CE-MRA</td>
<td>2</td>
<td>12</td>
<td>1</td>
<td>0</td>
<td>8</td>
<td>23</td>
</tr>
</tbody>
</table>

The standard CTA post-EVAR protocol and the standard MRI post-EVAR protocol without the dynamic CE-MRA is compared to the protocol with the additional dynamic CE-MRA.
workstation with 4D capabilities for reading the scans. With regard to the comparison of the MRI data to the CTA data, it should be noted that, for reasons of dose reduction, delayed CT series were not made in all patients. Only patients who had aneurysm sac enlargement at previous evaluations were subjected to delayed CT series. This could theoretically have resulted in an underestimation of the number of endoleaks found in the CT scans. However, the delayed series that were made, did not result in the detection of additional endoleaks. In clinical practice only selected patients should be subjected to delayed CT series, as the cumulated exposure of the patient to ionizing radiation would get unacceptably high. The use of dynamic MRA techniques may obviate the need for such delayed CT scans.

In our current dynamic CE-MRA scan, the acquisition of each 3D volume takes approximately 6.2 s. This fast image acquisition is achieved by making use of parallel imaging, which means that the sensitivity profiles of the receiver coils are used to combine simultaneously received signals from multiple coil elements into an image while scanning less k-space lines. A disadvantage of this acquisition technique is that scan planning is very important, since due to the parallel imaging reconstruction, fold-over artifacts project in the region of interest. In addition, the higher temporal resolution results in a decreased signal-to-noise ratio (SNR). However, in our experience this decreased SNR did not have an impact on the diagnostic value of the scans. Our main interest was imaging of contrast dynamics and since we used 20 ml of Gd-DTPA in a heavily T1-weighted scan, the intrinsic contrast to noise ratio (CNR) between the vessels and the background tissue was very high. Another problem of the dynamic scan is the moderate spatial resolution of the images. Each acquired volume is a low resolution version of the non-dynamic coronal 3D CE-MRA (scan 3 in our protocol). The lower resolution is the price to pay for the increased temporal resolution. This is reflected in the fact that small endoleaks could not be depicted using this technique. The spatial resolution of our dynamic scan probably was too low for this purpose. In the future, when receiver coils capable of applying higher SENSE factors in abdominal imaging become available, both spatial and temporal resolution might be improved.

Ghosting artifacts due to respiratory motion of the ventral wall present a difficult problem. Especially, in the dynamic series, since the 1-min duration of this scan makes it impossible to totally acquire it within a single breath hold. The average patient suffering from vascular disease will not be able to perform a breath hold for a period longer than 30 s. Artifacts can, however, be minimized in coronal scans, by placing the scan volume as far dorsally as possible. In some of the patients artifacts cannot be prevented due to the extent of the aneurysm to the abdominal wall.

Our main conclusion is that adding dynamic CE-MRA to the MRI protocol provides the observer with the dynamic information only otherwise available from DSA. Future studies will have to determine the exact value and place of dynamic CE-MRA in the EVAR follow-up. A larger study comparing a dedicated MRI protocol including dynamic MRA to the CTA-based follow-up protocol in patients with MR compatible stent grafts is currently being started at our institution.

References


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