Optimized time-resolved 3D contrast-enhanced MRA at 3T: Appreciating the feasibility of assessing cervical paragangliomas

Faisabilité de l’étude des paragangliomes cervicaux par ARM Dynamique 3D optimisée à 3T


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Summary

Objectives. — To describe an optimized 3D time-resolved contrast-enhanced MR angiography (3D TR-CE-MRA) at 3T in diagnosing head and neck paragangliomas and assessing their morphology and relation to neighboring vessels.

Methods. — In a prospective study, eight consecutive patients presenting cranial cervical masses suspected to be 10 paragangliomas were examined with 3D TR-CE-MRA at 3T. Two neuroradiologists evaluated the overall image quality, the presence of a paraganglioma, the maximum diameter, as well as the vessel invasion.

Results. — In all of the cases, the overall image quality was scored as good. The tumors (n = 10) were all visualized and localized. The mean maximum diameter was 32.7 mm [range 7—80]. Vessel invasion was assessed as uncertain in one case and improbable in nine cases.

Conclusion. — 3D TR-CE-MRA at 3T associated with conventional sequences facilitates a comprehensive investigation of paragangliomas, thus providing the anatomical and functional information.

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Introduction

Paragangliomas of the head and neck are closely aligned with the distribution of the parasympathetic nervous system [1]. Both computed tomography (CT) and magnetic resonance (MR) imaging are used to confirm the diagnosis, revealing a well-circumscribed, strongly enhancing mass with an erosion of adjacent bony structures and an encapsulated...
tumor with a salt & pepper-like appearance [1]. Differentiation from other lesions is difficult when conventional non-invasive techniques are used [2]; digital subtraction angiography (DSA) remains necessary for assessing vascular tumor architecture, as it provides hemodynamic information. Diagnosis of paragangliomas is facilitated by the typical angiographic appearance: a hypervascular mass (blush) with enlarged feeding arteries and early draining veins [3]. In preoperative imaging studies, DSA is a reliable tool for assessing the location of the mass in relation to the internal carotid artery (ICA) and internal jugular vein (IJV), and evaluating ICA or IJV invasion. However, as DSA is invasive, requiring a radiation dose along with an iodinated contrast material injection, it cannot be repeated regularly. Time-resolved contrast-enhanced (TR-CE) MRA has proven effective in demonstrating intracranial and cervical neurovascular pathologies [4], and has emerged as an alternative technique to DSA [5]. It is a non-invasive technique whereby multiple phases of first-pass gadolinium contrast agent injection are imaged. Consequently, some authors have discussed its utility in differentiating paragangliomas from other tumors or vascular abnormalities [4,6]. Previous reports on the use of TR-CE-MRA reveal a maximum temporal resolution of 1.5 s per dynamic image without a three-dimensional (3D) isotropic acquisition; or a higher spatial resolution with isotropic 3D imaging, but without the necessary hemodynamic information. The recent development of high-field MRI allows for sub-second temporal resolution 3D sequences with high isotropic spatial resolution [7].

This study aimed at assessing the potential applications of optimized 3D TR-CE-MRA at 3T associated with conventional MR imaging in the diagnosis of paragangliomas.

### Materials and methods

Data were prospectively collected from eight patients (7 women, 1 man; mean age 55 years, ranging from 31 to 76), showing cranial cervical masses suspected to be 10 paragangliomas, and referred to our center between February 2006 and October 2007 (Table 1). The final diagnosis was based on DSA (8 tumors), somatostatin receptor scintigraphy (10 tumors), and/or histopathology examination (5 tumors) (Table 1).

MR imaging was performed using a 3.0T system (Achieva, Philips Medical Systems, Best, The Netherlands) with 8-channel phased array head coils enabling exploration of the head and neck. A 3D T1-weighted fast gradient-echo (FFE) sequence was used for 3D TR-CE-MRA (TR/TE/\(\alpha\) = 2.8 ms/0.93 ms/20\(^\circ\), acquired/reconstructed matrix size = 256 \(\times\) 256 mm/288 \(\times\) 288 mm, field of view = 260 \(\times\) 260, acquired/reconstructed isotropic voxel size = 1.02 \(\times\) 1.02 \(\times\) 1.80 mm/0.90 \(\times\) 0.90 \(\times\) 0.90 mm, sagittal acquisition, and volume = 100 sagittal slices \(\times\) 0.90 mm). 3D TR-CE-MRA was performed using the CENTRA keyhole technique (central k-space diameter of 20%) along with parallel imaging (sensitivity encoding [SENSE]) and a reduction factor of 5.4. The central part of k-space was sampled 25 times with a temporal resolution of 1.2 s.

### Table 1 - Clinical presentation, location, and paraclinical data of 10 paragangliomas.

<table>
<thead>
<tr>
<th>Patient Nr</th>
<th>Gender / Age</th>
<th>Clinical presentation</th>
<th>Location</th>
<th>Maximal diameter (mm)</th>
<th>Histopathology examination</th>
<th>DSA</th>
<th>Somatostatin receptor scintigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F/76</td>
<td>Pulsatile tinnitus</td>
<td>L middle ear</td>
<td>13.5</td>
<td>NA</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>F/66</td>
<td>Dysphonia</td>
<td>L vagal nerve</td>
<td>60</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>M/59</td>
<td>Dysphagia</td>
<td>R carotid artery bifurcation</td>
<td>48</td>
<td>NA</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>F/57</td>
<td>Asymptomatic, hereditary paraganglioma syndrome</td>
<td>R jugular foramen</td>
<td>35</td>
<td>NA</td>
<td>NA</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>F/31</td>
<td>Pulsatile tinnitus</td>
<td>R jugular foramen</td>
<td>13</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>M/38</td>
<td>Cervical mass</td>
<td>R carotid artery bifurcation</td>
<td>15</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>F/48</td>
<td>Pulsatile tinnitus, hypoacusia</td>
<td>R middle ear</td>
<td>12</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>F/67</td>
<td>Pulsatile tinnitus, hypoacusia</td>
<td>L middle ear</td>
<td>24</td>
<td>+</td>
<td>NA</td>
<td>+</td>
</tr>
</tbody>
</table>

DSA: digital subtraction angiography; F: female/M: male; L: left/R: right; N/A: not available; +: aspect of paraganglioma.
followed by a 6.2 s reference dataset. Total imaging time was 36.2 s. Parameters were optimized so as to achieve high isotropic spatial resolution while maintaining a satisfactory temporal resolution. The examination began with a 20 ml meglumine gadoterate (Guerbet, France) bolus, administered intravenously at a rate of 3 ml/s using an automatic injector (Medrad, Indianola, PA, USA), followed by a 30 ml saline flush. After 3D TR-CE-MRA was performed, the first dynamic volume was subtracted from the subsequent 3D volumes. The subtracted images were transferred to a workstation (ViewForum; Philips Medical Systems, Best, The Netherlands) and maximum intensity projection (MIP) reconstructions were then performed in the coronal, sagittal, and axial planes. Conventional MRI included T1 pre-contrast with and without Fat Sat, T2 with Fat Sat, and T1 post-contrast with Fat Sat (performed after 3D TR-CE-MRA).

Two experienced neuroradiologists evaluated the 3D TR-CE-MRA findings and reached a consensus. The images were analyzed in increments and assessed on a workstation. Firstly, overall image quality was scored on a 3-point scale (good, acceptable, and insufficient) and the presence of artifacts (motion or parallel imaging) was assessed. Secondly, the following diagnostic criteria were assessed: early and intense enhancement, number, and location (the carotid artery bifurcation, the jugular foramen, along the vagal nerve, and within the middle ear), and the maximum diameter was measured. Thirdly, the presence of a paraganglioma was assessed on a 3-point scale as follows: 2 = probable, 1 = uncertain, 0 = improbable. Lastly, vessel invasion, char-

Figure 1  Arterial (A) and venous (B) phase sagittal MIP reconstruction of 3D TR-CE-MRA in patient Nr 6 shows early and intense enhancement in the right carotid bifurcation, suggestive of a right carotid paraganglioma (white arrow). The right common carotid artery DSA lateral view (C) shows the same early and intense enhancement in the right carotid bifurcation (black arrow).

Figure 2  Arterial coronal phase MIP reconstruction of 3D TR-CE-MRA (A) in patient Nr 5 shows early and intense enhancement suggestive of a bilateral jugular foramen paraganglioma (white arrows), and the left common carotid DSA anteroposterior views (B, C) show the same early and intense enhancement (black arrow).
Time-resolved 3D contrast-enhanced MRA at 3T for paraganglioma

Figure 3  Arterial sagittal (A) and coronal (B) phase MIP reconstructions of 3D TR-CE-MRA in patient Nr 1 shows early and intense enhancement suggestive of a left middle ear paraganglioma (white arrow), and the left common carotid DSA lateral view (C) shows the same early and intense enhancement (black arrow).

characterized by a narrowing and an irregularity of the ICA along with a thrombosis of the IJV, was assessed as probable, uncertain, or improbable. A third neuroradiologist evaluated the conventional MR images of all the patients.

Results

The overall image quality of 3D TR-CE-MRA was scored as good in all of the cases. No artifacts were observed. Early and intense enhancement was noted in 10 lesions (Figs. 1–3). Among the 10 paragangliomas, three were located in the carotid artery bifurcation (1 unilateral, 1 bilateral) (Fig. 1), three in the jugular foramen (Fig. 2), three within the middle ear (Fig. 3), and one along the vagal nerve. The mean maximum diameter was 32.7 mm [range 7–80]. The presence of a paraganglioma was assessed as probable in all of the cases. Vessel invasion was assessed as uncertain in one case, and improbable in nine cases.

In all 10 tumors, conventional MRI revealed well-circumscribed, strongly enhancing masses with a salt and pepper-like appearance in eight of them.

Discussion

3D TR-CE-MRA with high-temporal resolution and isotropic spatial resolution at 3.0T is an efficient approach for assessing paragangliomas. This method results in a rapid and intense enhancement of paragangliomas, and is complementary to the well-circumscribed, strongly enhancing masses with a salt and pepper-like appearance which are typically seen on conventional MRI sequences.

This technique is conducive to the study of head and neck tumors and facilitates the elimination of other differential diagnoses [6]; characterized by its enhancement dynamics, it allows for a better distinction of the arterial and venous blood supplies of highly vascularized lesions such as paragangliomas.

Prior to the recent technological developments, the use of TR-CE-MRA was limited, owing to the small number of sections translating the temporal resolution, or to a large section thickness with lower spatial resolution. TR-CE-MRA imaging at 1.5T was reported as a highly sensitive tool for the diagnosis of paragangliomas based on its large acquisition volumes and spatial resolutions, regardless of the temporal resolution [4]. However, the lack of hemodynamic information makes it difficult to detect multifocal or small paragangliomas and their typical angiographic “blush” appearance. Since then, 3D TR-CE-MRA techniques have improved thanks to parallel imaging and k-space sampling strategies, and more recently, the use of high field imaging. As a result, sequences now combine large section thickness and higher temporal and spatial resolution, thereby leading to improved image quality [7]. The sequence combining CENTRA keyhole and SENSE is commonly used as it is considered to be the most effective. The specificity of “keyhole” is to focus on contrast data (center of k-space) rather than spatial resolution data (periphery of k-space), leading to high contrast values. Keyhole strategies provide better spatial resolution, at the expense of contrast, with ringing and edge vascular artifacts. To limit this drawback, this technique is combined with CENTRA. Improved 3D TR-CE-MRA has already proven useful for the classification and follow-up of arteriovenous malformations [7]. Further studies would be pertinent in determining and evaluating various quantitative parameters, such as relative tumor/arterial peak signal intensity, thanks to the necessary hemodynamic information provided by this technique [6]. Moreover, as the spatial resolution of this technique is lower than that of DSA, the problem of its application in the assessment of the vascularization of paragangliomas must still be addressed.

However, this technique has some limitations. Compared to DSA, owing to its lower spatial resolution, 3D TR-CE-MRA does not permit selective or superselective vessel characterization, and therefore the possibility of endovascular treatment before surgery.
Conclusions

High temporal and spatial resolution 3D contrast-enhanced MR angiography at 3.0T appears to be a promising non-invasive technique for the diagnosis of paragangliomas thanks to the anatomical and functional information provided.

Conflicts of interests

None.

References


