Image fusion for preoperative evaluation of vertebral artery in a patient with atlantoaxial vertical subluxation and chronic renal failure

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Abstract For preoperative evaluation of the vertebral artery (VA) at the craniovertebral junction, 3-dimensional (3-D) computed tomography (CT) angiography can simultaneously and precisely depict the location of the VA and the circumferential osseous tissues. However, this procedure has the risk of contrast-induced nephropathy, especially when patients have pre-existing renal impairment. We report the case of a 73-year-old woman with rheumatoid arthritis and concomitant chronic renal failure in whom severe myelopathy developed due to atlantoaxial vertical subluxation and subaxial subluxation. We planned to perform C1 laminectomy and C3–C7 laminoplasty, but to avoid the risk of intraoperative VA injury, we applied a fusion image technique of 3-D magnetic resonance (MR) angiography and co-registered 3-D CT that allowed for virtual assessment preoperatively of the VA courses, instead of 3-D CT angiography. Through the 3-D hybrid MR angiography–CT images, we could predict, in detail, the VA courses and the surrounding bony structures. At surgery, we found that the locations of the VAs were identical to that predicted on the preoperative image fusion analysis. We conclude that our image fusion techniques possess accurate diagnostic value for detecting arterial course, and could be applicable for patients in whom administration of contrast media should be avoided due to specific conditions, such as drug allergy and chronic renal failure.

Keywords Hybrid · Fusion image · Vertebral artery · Craniovertebral junction

Introduction

Patients with rheumatoid arthritis occasionally suffer from upper cervical lesions such as atlantoaxial vertical subluxation, which, in some cases, necessitates decompression surgery for the treatment of myelopathy. Previous reports of surgeries for cases with severe upper cervical spine deformities have described the utility of three-dimensional (3-D) computed tomography (CT) angiography for preoperative evaluation of the course of the vertebral artery (VA). 3-D CT angiography can distinguish the precise location of the VA and the circumferential osseous tissues simultaneously [5]. However, radiological examinations using contrast media entail the risk of contrast-induced nephropathy, especially in patients with pre-existing renal impairment [3].

In this article, we report the case of a patient with rheumatoid arthritis and concomitant chronic renal failure in whom severe myelopathy developed due to atlantoaxial vertical subluxation. For this patient, we did not perform 3-D CT angiography in order to avoid the risk of contrast-induced nephropathy. Instead, we applied a fusion image technique of 3-D magnetic resonance (MR) angiography and co-registered 3-D CT that allowed virtual preoperative simulation of the VAs at the craniovertebral junction.

Case report

Clinical profile

A 73-year-old woman visited our clinic with complaints of gait disturbance, clumsiness of the hands bilaterally, and occipitalgia. She had suffered from rheumatoid arthritis for 17 years and, as a complication, had developed chronic

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renal failure with blood urea nitrogen and serum creatinine levels of 40.0 and 1.5 mg/dl, respectively, and a glomerular filtration rate of 28.0 ml/min. At age 65, she had undergone a total right knee replacement surgery and was able to walk without any support following surgery. One month prior to the first visit to our clinic, however, she was unable to stand up without support and was unable to use her hands in daily activities, because of progressive myelopathy. Neurological examinations at the first visit revealed loss of both motor and sensory functions below the C5 level. The patient had received conservative therapy using cervical orthosis, but her myelopathy had not improved.

A cervical lateral radiograph and a mid-sagittal CT with reconstruction showed atlantoaxial vertical subluxation, kyphosis from C4 to C6, and retrospondylolisthesis at C5 (Fig. 1a). A T2-weighted MR mid-sagittal image revealed severe posterior compression of the spinal cord at the C1 level. The MR image also showed multi-level anterior compression of the spinal cord at the middle-lower cervical spine by bulging discs and, posteriorly, by thickened ligamentum flavum (Fig. 1b).

To decide the surgical procedure for the craniovertebral junction, we provided a standardized informed consent for the patient. We explained the relative advantages and disadvantages of C1 laminectomy alone and C1 laminectomy plus occipito-cervical posterior fusion. The patient did not select the addition of occipito-cervical posterior fusion in spite of the possibility of future progression of basilar

invagination. Thus, we decided to perform decompression surgery using a posterior approach with a C1 laminectomy and laminoplasty from C3 to C7.

To avoid the risk of VA injury during the C1 laminectomy, we initially planned to perform 3-D CT angiography for evaluating the course of the VAs bilaterally at the craniovertebral junction, but decided against this procedure due to the risk of contrast-induced renal failure. As an alternative, we applied a multimodality image fusion; 3-D MR angiography and 3-D CT was performed sequentially, and then software fusion was used to align the two sets of images.

Image fusion of 3-D MR angiography and 3-D CT

CT data of the patient's cervical spine were acquired with a 16-row multi-detector CT (LightSpeed ULTRA 16, GE Healthcare, Milwaukee, WI) using the following protocol: tube voltage, 140 kV; tube current, auto mA (100–300 mA); rotation time, 1 s; pitch factor, 1.375; beam, 10 mm; matrix, 512 × 512; section thickness, 1.25 mm; configuration, 16 × 0.625 mm; field of view, 96 mm (0.185 mm/pixel); reconstruction 50% overlap. A total of 225 pieces of continuous source axial volumetric data were obtained.

MR angiography was performed with a clinical magnetic resonance imager (Achieva Nova Dual 1.5T, Philips Medical Systems, Eindhoven, The Netherlands), using a

Fig. 1 Preoperative computed tomography (CT) (a) and magnetic resonance (MR) (b) images of a 73-year-old woman with rheumatoid arthritis and severe myelopathy. A mid-sagittal CT reconstruction image (a) shows atlantoaxial vertical subluxation and subaxial subluxation. A T2-weighted MR mid-sagittal image (b) demonstrates spinal cord compression at C1 and middle-lower cervical spine

dedicated commercially available 16-channel neurovascular array coil with sensitivity encoding (SENSE, Philips), and data were obtained using a 3-D TOF, FFE sequence. We used the following protocol: TR/TE, 20/6.9; flip angle, 16°; matrix, 256 × 128; section thickness, 1.0 mm; field of view, 180 × 135 mm; SENSE factor, 2.0; scan time, 6 min 13 s. A total of 210 pieces of continuous source axial volumetric data were obtained, and were reconstructed for the 3-D MR angiography images (Fig. 2).

Between the CT and the MR angiography examinations, we adjusted the patient's position. The vertical interval between the headrest and the mat of each device was adjusted to equal height, and we aligned the angle of the patient's mandible between examinations by matching a place mark on the patient's cheek and the devices' aiming beam.

Post-processing was performed on a regular Apple Macintosh 2.5 GHz Power PC G5 running OS X and open-source OsiriX imaging software (Version 3.0.1; OsiriX Foundation, Geneva, Switzerland, <http://www.osirix-viewer.com>) [1]. The CT images were fused to the 3-D MR angiography images according to the method described in the OsiriX tutorial online seminars (free registration is required for review). Briefly, regions of interest were identified that included the length of the VA and surrounding bony

structures from the occipital bone to T2 vertebrae. The OsiriX surface-rendering algorithm was used to produce 3-D reconstructions of the CT images by setting the lower threshold to just above the signal intensity of cortex bone. A second surface-rendered image from the 3-D MR angiography data was superimposed on this image to produce a single false-color reconstruction of the structure. We performed point-base registration among the two sets of images, referring to the foramen transversarium for 5 points. Vessels visualized on angiography were defined as arteries and those appearing on 3-D CT were identified as bones. With this technique, fused images of CT and MR angiography were produced and objectively demonstrated the C1 posterior arch and nearby arteries. The images could be rotated to be viewed from various angles.

In the current case, the C1 posterior arch was translated anteriorly and laterally to the right side. Due to this translation of C1, the left VA was seen to run relatively near the central portion of C1 posterior arch and to enter the spinal canal at the cranial aspect of C1 (Fig. 3a–c).

Operation and postoperative course

We performed a C1 laminectomy and C3–C7 laminoplasty. Intraoperatively, we exposed the C1 posterior arch and identified the courses of the bilateral VAs at the cranial aspect of C1 by Doppler ultrasonography. We found that the left VA localized nearer to the center of C1 posterior arch than the right VA, as predicted preoperatively by the fusion images of MR angiography and CT. All surgical procedures were undertaken carefully so as to avoid injury to the VAs and were accomplished uneventfully.

After surgery, the patient demonstrated intact renal function and her neurological deficits and occipitalgia gradually improved. Postoperatively, the patient's cervical spine was stabilized with a cervical collar for 3 weeks. MR images 1 month after surgery showed adequate decompression of the spinal cord at C1 and C3–C7. At the final follow-up 1 year after surgery, no progression of basilar invagination occurred. She was able to walk without a cane, and no further symptoms had developed.

Discussion

Previous studies have shown that MR angiograms provide useful information for identifying VA anomalies at the regions around the cervical spine [2]. MR angiography has the advantage of being less invasive because no contrast media is required. However, MR angiography cannot simultaneously visualize both the artery and the surrounding osseous tissue, nor can it analyze the reciprocal anatomy of both tissues.

Fig. 2 An anterior–posterior view of 3-dimensional (3-D) MR angiography image. Arrowheads indicate vertebral arteries (VAs)

Fig. 3 Hybrid 3-D MR angiography–CT images (**a** posterior view, **b** posterior–superior view, **c** left lateral view) visualizing the relationship between the VAs and the C1 posterior arch. Images of the VA obtained by MR angiography are stained in red and those of vertebral osseous components obtained by CT are stained in gray

Recently, the utility of 3-D CT angiography has been described for evaluating VA anomalies at the craniovertebral junction [5]. 3-D CT angiography has several advantages in that it can depict VA images more precisely and can reconstruct the image, displaying the VA and surrounding osseous tissue simultaneously [5]. Despite the utility of 3-D CT angiography for preoperative evaluation of the VA, 3-D CT has a disadvantage in that this examination requires contrast media and thus has a possible risk of contrast-induced nephropathy, particularly in patients with pre-existing renal disorders. Previous studies in patients undergoing coronary angiography have shown that the rate of development of contrast-induced nephropathy in high-risk patients is estimated at 20–30% [3]. Thus, when working with a patient suffering from pre-existing chronic renal failure, it is necessary to be extra vigilant for the occurrence of contrast-induced nephropathy following 3-D CT angiography.

In recent years, there has been rapid development of diagnostic imaging using the techniques of multimodality image fusion [4]. Previous studies have shown the usefulness of hybrid images such as PET/CT and SPECT/CT to better understand the combination of anatomy and function [4]. In the present case, because of the presence of pre-existing renal impairment, we avoided the use of 3-D CT angiography for evaluating the VA course at the craniovertebral junction, but performed image fusion of MR angiography and CT. To the best of our knowledge, this is the first report describing the visualization of the VAs at the craniovertebral junction using such a fusion image technique. Through the 3-D hybrid MR angiography–CT images, we could predict, in detail, the course of the VAs as well as the surrounding bony structures. At surgery, we found that the location of VAs was identical to that

predicted on the preoperative image fusion analysis. Thus, we believe that our technique of image fusion of MR angiography and CT possesses accurate diagnostic value for detecting the course of arteries, and could be applicable for patients in whom administration of contrast media should be avoided secondary to conditions such as drug allergy and chronic renal failure.

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Conflict of interest statement None of the authors has any potential conflict of interest.

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