Dynamic Computed Tomography Myelography for the Investigation of Cervical Degenerative Disease

—Technical Note—

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Abstract

Dynamic computed tomography (CT) myelography was conducted in 15 patients with cervical degenerative disease to assess the lesions responsible for their symptoms. CT myelography was performed using a multi-detector row helical CT system in dynamic positions (flexion or extension or both) in addition to the neutral position. Fine sagittal reconstructed images could be obtained in addition to axial images. This method provided static information including cervical vertebral body deformities, and good contrast images of the spinal cord, nerve roots, and cerebrospinal fluid space. In addition, laterality of the offending lesion and changes exaggerated by cervical motion were clearly shown in both axial and sagittal images. Ten of 15 patients demonstrated dynamic changes including dynamic canal stenosis or spinal cord impingement. The operative strategies were changed based on dynamic CT myelography findings in three of the 15 patients. Dynamic CT myelography can provide the axial and sagittal images required for flexion-extension studies, and in combination with conventional imaging modalities, provides valuable information for determining treatment strategies and objectives.

Key words: cervical degenerative disease, cervical spine, dynamic computed tomography myelography, multi-detector row helical computed tomography

Introduction

Cervical spine degeneration is a common disease, but the association between the symptoms and radiographically observed structural abnormalities is important to assess accurately, including both static aberrant lesions and functional factors.7,9,17 Various modalities have been applied to assess cervical degenerative disease, including conventional radiography, myelography, computed tomography (CT), CT myelography, and magnetic resonance (MR) imaging.1,2,6 Additional dynamic studies (extension and flexion) are also considered valuable for evaluating cervical disease, because dynamic factors are strongly believed to contribute to the pathogenesis of cervical degenerative disease.7,17 Recently, kinematic MR imaging studies have been performed to define the physiological changes that occur in the subarachnoid membrane as well as the cervical cord and the surrounding ligaments at different positions of flexion and extension of the neck.3 However, such studies are relatively time-consuming and cannot demonstrate bony changes or calcified lesions.3,9,11,12,15

In many institutions, CT myelography is still considered an essential preoperative modality, although the use of MR imaging has been increasing. However, no dynamic studies with CT myelography have been reported, probably because of the possibility of excessive radiation exposure and a single-detector CT system cannot provide clear sagittal reconstructed images. Multi-detector row helical CT systems can now acquire data over a broader area with better longitudinal spatial resolution and shorter scanning time than single-detector row scanners. Such data can be effectively reconstructed into images of specific planes.19

We performed dynamic CT myelography with a multi-detector row helical CT system including extension and flexion to determine treatment or surgical strategy, and to clarify various issues,
Table 1  Summary of cases

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)/Sex</th>
<th>Symptoms</th>
<th>Underlying diseases</th>
<th>Additional dynamic CT myelography findings</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73/M</td>
<td>rt upper limb paresis</td>
<td>C4-5 disc herniation</td>
<td>multi-segmental cord impingement</td>
<td>laminoplasty</td>
</tr>
<tr>
<td>2</td>
<td>75/M</td>
<td>rt upper limb paresis</td>
<td>multi-segmental spur formation</td>
<td>multi-segmental cord impingement</td>
<td>laminoplasty</td>
</tr>
<tr>
<td>3</td>
<td>74/F</td>
<td>bil upper limb paresis and gait disturbance</td>
<td>multi-segmental spur formation</td>
<td>multi-segmental cord impingement</td>
<td>laminoplasty</td>
</tr>
<tr>
<td>4</td>
<td>79/M</td>
<td>bil upper limb paresis</td>
<td>multi-segmental spur formation</td>
<td>multi-segmental cord impingement</td>
<td>laminoplasty</td>
</tr>
<tr>
<td>5</td>
<td>64/M</td>
<td>spastic gait disturbance</td>
<td>C4-5 and C5-6 spur formation</td>
<td>multi-segmental cord impingement</td>
<td>laminoplasty</td>
</tr>
<tr>
<td>6</td>
<td>59/M</td>
<td>bil upper limb paresis</td>
<td>multi-segmental canal stenosis</td>
<td>multi-segmental cord impingement</td>
<td>laminoplasty</td>
</tr>
<tr>
<td>7</td>
<td>36/F</td>
<td>lt upper limb weakness and numbness</td>
<td>C5-6 spur formation</td>
<td>—</td>
<td>C5-6 anterior fusion</td>
</tr>
<tr>
<td>8</td>
<td>50/F</td>
<td>rt upper limb paresis (Keegan type)</td>
<td>C5-6 spur formation</td>
<td>C5-6 dynamic canal stenosis</td>
<td>C5-6 anterior fusion</td>
</tr>
<tr>
<td>9</td>
<td>50/F</td>
<td>bil leg spasticity</td>
<td>C4-5 and C5-6 spur formation</td>
<td>—</td>
<td>C4-5 and C5-6 anterior fusion</td>
</tr>
<tr>
<td>10</td>
<td>54/M</td>
<td>lt upper limb paresis</td>
<td>C5-6 disc herniation</td>
<td>single-segment cord impingement</td>
<td>C5-6 anterior fusion</td>
</tr>
<tr>
<td>11</td>
<td>39/M</td>
<td>lt upper limb pain</td>
<td>C6-7 spur formation</td>
<td>C6-7 dynamic canal stenosis</td>
<td>C6-7 anterior fusion</td>
</tr>
<tr>
<td>12</td>
<td>54/M</td>
<td>bil upper limb numbness</td>
<td>C3-4 spur formation</td>
<td>—</td>
<td>conservative</td>
</tr>
<tr>
<td>13</td>
<td>51/M</td>
<td>bil upper limb clumsiness</td>
<td>C5-6 spur formation</td>
<td>C5-6 dynamic canal stenosis</td>
<td>conservative</td>
</tr>
<tr>
<td>14</td>
<td>68/F</td>
<td>lt upper limb pain</td>
<td>C5-6 spur formation</td>
<td>C5-6 dynamic canal stenosis</td>
<td>conservative</td>
</tr>
<tr>
<td>15</td>
<td>68/M</td>
<td>bil upper limb weakness</td>
<td>C7-T1 disc herniation</td>
<td>—</td>
<td>conservative</td>
</tr>
</tbody>
</table>

CT: computed tomography.

including exposure to radiation and contrast medium.

Materials and Methods

This study included five women and 10 men aged 36–79 years (mean age 60 years) with cervical degenerative disease admitted to our institution between October 2003 and January 2005 (Table 1). All patients had radiological and long-standing clinical signs of cervical spondylotic myelopathy or radiculopathy. All patients were assessed by careful neurological examination. Cervical radiography and MR imaging were obtained on admission. CT myelography was performed about half an hour after injection of the contrast medium iohexole (Omnipaque; Daiichi Pharmaceutical Co., Ltd., Tokyo) (240 mgI/ml, 10 ml) into the lumbar cerebrospinal fluid space to allow homogeneous diffusion in the cerebrospinal fluid space. Additional dynamic motion study (flexion or extension or both) was performed to the extent possible as limited by the patients. If a symptom was definitely induced by a certain posture, the scan was performed only in that given position (flexion or extension) in addition to the neutral position. Otherwise, the flexion, extension, and neutral positions were scanned.

The multislice CT unit (Aquilion; Toshiba Medical System Inc., Tokyo) can provide high resolution images in the axial view as well as sagittal and coronal reconstructed images at the same time. The CT scans were obtained with four different rows of detectors using the following parameters: 120 kV, 100–150 mA, 1.00-mm collimation, 6.0 mm/rot table speed, and 0.5 second rotation time. Informed consent regarding the possible increased radiation dose of the dynamic study and adverse effects caused by the contrast medium was obtained from all patients.

Cervical radiography and MR imaging identified the underlying diseases as two cases of intervertebral disc herniation, six of multi-segmental spur formation, and seven of single segmental spur formation (Table 1). Dynamic changes to the spine, including vertebral instability and spinal cord impingement, and changes to other surrounding...
structures occurring due to cervical motion change were assessed on the axial and sagittal reconstructed images. Spinal cord impingement was visualized as spinal cord compression due to spinal instability, hypotonic ligamentum flavum, or dynamic annular bulging. Dynamic canal stenosis was defined as a distance between the posteroinferior edge of the upper vertebral body and the superior edge of the lower vertebral body at the flexion or extension position of less than 12 mm.

In addition to the clinical examinations, the radiation dose was measured by dosimetry-equipped CT. The values were almost equal to those measured by a phantom study at Toshiba Medical System, Inc. The main dosimetric quantity used in CT is the weighted CT dose index (CTDIw), which indicates the radiation exposure per 10 mm. Details of the dosimetric quantities used in CT including the CTDIw are described elsewhere.

The mean scan-time for the cervical spine in one position was about 2 minutes. Therefore, less than 7 minutes were required to perform the entire study with flexion-extension scanning. High-quality images, especially sagittal images, could be reconstructed from axial images within 10 minutes. If the examination was performed especially to investigate motion changes using detailed axial images as well as sagittal images, the tube current was set at 150 mA. At this setting, the CTDIw incurred for one position (ex. neutral position) was 15.2 mGy, so the study was limited to two scans (neutral position and another position) to limit radiation exposure. If the examination was intended to examine motion change on sagittal images only, the tube current was set as low as 100 mA, and the CTDIw incurred for one position was 10.1 mGy.

Results

Dynamic CT myelography of all 15 patients clearly revealed the spinal cord and the cerebrospinal fluid space, together with any deformities of the cervical spine, spinal cord impingement, or spur formation. Sagittal reconstructed images provided several contiguous slices across the vertebral bodies, so clearly displayed vertebral bony changes and functional cord impingement, as well as simultaneously depicting the offending lesion including lateral spur or disc hernia.

Clinical outcome and radiological characteristics are summarized in Table 1. Dynamic changes such as dynamic canal stenosis and cord impingement were clearly observed in 10 of the 15 patients on sagittal images taken using tube current of 100 mA. Changes in nerve roots or neural foramen could be observed in both neutral and extension positions, as in Cases 7, 8, 10, and 11, on axial images taken with tube current of 150 mA (Fig. 1).

Treatment and/or surgical strategy was decided based on these dynamic radiological findings together with the neurological and MR imaging findings. Cases 1–6 had multi-segmental cord impingement, so we selected expansive laminoplasty. Cases 7–11 had segmental dynamic changes or lateral spur formation causing symptoms in the sagittal as well as the axial views, so we performed anterior fusion. Cases 12–15 were managed conservatively because the degenerative changes or dynamic alterations were less severe. The symptoms of all patients had improved at follow up. No adverse effects were observed except for one patient who complain of post-spinal headache for a few days after dynamic CT myelography.

Illustrative Cases

Case 1: A 73-year-old man presented with a history of clumsiness after minor head trauma, with moderate numbness in both hands, persisting for 1 month. Neurological examination on admission revealed 4/5 strength by the manual muscle test and moderate numbness in both hands as well as spastic gait. The deep tendon reflex showed hyperreflexia in the bilateral lower extremities. MR imaging clearly revealed intervertebral disc herniation and mild cord compression at C4-5 (Fig. 2). Sagittal reconstructed images of CT myelography clearly showed mild cord compression due to a hard disc herniation at C4-5 in the flexion and neutral positions (Fig. 3A, B). However, more severe forms of multi-segmental cord impingement from the C4-5...
to the C5-6 intervertebral levels were seen in the extension position (Fig. 3C).

Based on these clinical and radiological findings, we devised a treatment plan of posterior decompressive laminoplasty rather than anterior fusion to relieve the multi-segmental cord impingement. After the operation, the patient’s spastic gait was remarkably improved, and he returned to normal daily life without requiring support 1 month after discharge.

Case 8: A 50-year-old woman presented with paresis in the right biceps muscle which occurred after waking up one morning. She reported that, while she was sleeping, her neck might have been extended, and she had already noticed paresis in the right upper limb when she woke up. The deep tendon reflex revealed that right biceps and brachioradialis reflexes were diminished. The manual muscle test showed 2/5 strength in the right upper extremity. MR imaging of the cervical spine demonstrated mild degenerative changes at C5-6 (Fig. 4). Sagittal images of CT myelography in the neutral position revealed mild spur formation at C5-6 (Fig. 5A) and axial images clearly identified bilateral nerve roots running in the subarachnoid space (Fig. 5C). However, sagittal images clearly pictured more protrusive findings in the extension position, as the distance between the posteriorinferior edge of the upper vertebral body and the superior edge of the lower vertebral body was 9 mm, indicating dynamic canal stenosis (Fig. 5B). Axial images also disclosed right-sided spur formation in the extension position, and the nerve roots were not visible (Fig. 5D).

These findings were compatible with the symptom induced by neck extension during sleep. The diagnosis was Keegan-type cervical spondylosis. We performed C5-6 anterior fusion with the primary goal of removal of the right lateral spur formation. The postoperative course was uneventful, and the patient was almost symptom-free 3 months after the operation.
Discussion

Multi-detector row CT can scan a large area along the long axis of a patient in a short time. The data sets obtained using this system consist of cubical voxels that range in size from submillimeter to several millimeters, so the reconstructed images have good spatial resolution in the longitudinal direction. Using this technology, dynamic CT myelography could provide clearly contrasted images of the vertebral bones, spinal cord, nerve roots, cerebrospinal fluid space, and other surrounding structures on the sagittal reconstructed images as well as the axial images. Such rapid multi-detector row CT is very useful when dynamic axial and sagittal images are needed in addition to neutral position images. In our study, multi-detector row CT took just 7 minutes to obtain such images, contrast to the long time required for dynamic MR imaging. Therefore, patients suffering from intractable neck pain or difficulty keeping the neck loaded for a relatively long time can be examined. Multi-detector row CT can also demonstrate bony changes such as spur formation, vertebral instability, ossified lesions, and so on more clearly than MR imaging.

The dynamic radiological findings were very useful for determining operative strategies and objectives in the present patients, and helped to achieve good results. MR imaging and CT myelography in the flexion and neutral positions clearly depicted disc herniation at C4-5 as the pathognomonic finding related to the symptoms in Case 1. However, the sagittal images of CT myelography in the extension position revealed the more important finding of multi-segmental cord impingement from the C4-5 to C5-6 intervertebral levels. Therefore, we performed posterior decompressive laminoplasty. The sagittal images showed dynamic canal stenosis and the axial images showed disappearance of the nerve root and aggravation of right-sided spur protrusion in the extension position in Case 8. We therefore performed anterior fusion in this patient with special attention to removing the right-sided spur formation. MR imaging showed C4-5 and C5-6 spur formation in Case 5. In contrast, dynamic CT myelography demonstrated multi-segmental cord impingement in the extension position. We selected laminoplasty based on these findings. Dynamic CT myelography provided information that was crucial to our treatment decision-making in Cases 1, 5, and 8.

Radiation exposure will inevitably be a problem with this method. A relatively high CTDIw of 10.1 mGy is needed for CT myelography in one position with tube current of 100 mA. Therefore, the total CTDIw would be 30.3 mGy for a full study including flexion, neutral, and extension positions. Moreover, if the tube current is increased to 150 mA, the CTDIw will be 15.2 mGy for one position and 30.4 mGy for two positions. The European Guidelines on Quality Criteria for Computed Tomography: EUR 16262 EN suggest maximum levels for CTDIw of 35 mGy for the spinal cord and 70 mGy for the vertebral and paravertebral structures that should not be exceeded unless for special clinical reasons. The total CTDIw in the current study remained within the limits of these guidelines.

The use of contrast medium also carries the risk of adverse effects. Investigation of myelography with the water-soluble nonionic contrast medium iohexol revealed that 70% of patients reported no reactions.
in the 24 hours after the procedure.\textsuperscript{18} Headache was the most prevalent adverse reaction (19%), followed by nausea (8%), vomiting (3%), and dizziness (2%). The onset of most reactions occurred within the first 2 to 3 hours and usually lasted no more than 10 to 12 hours. No changes of vital signs or psycho-organic syndrome including convulsion were reported.\textsuperscript{18}

Dynamic CT myelography should not become a routine examination of cervical degenerative diseases because of these risks. Indications for this method are as follows: patients with symptoms deteriorated by dynamic changes, and symptoms without causative lesions definitely determined by conventional methods including cervical radiography and MR imaging. In particular, if lateral bony lesions such as osteophytic spurs or ossified ligaments cause root or compressive (e.g. Keegan-type cervical spondylosis) indicated by dynamic changes, dynamic CT myelography is better than kinetic MR imaging for diagnosis, because a single scan with the reconstruction technique can provide many slices of both axial and sagittal views from right to left and adequate information regarding bony changes. If the symptoms are constantly induced by a given position, dynamic CT myelography can be limited to a scan in that position.

Dynamic CT myelography using multi-detector row helical CT systems can rapidly provide the axial and sagittal images required for flexion-extension studies. Dynamic CT myelography can be combined with neurological examination and other conventional imaging techniques to accurately identify the lesions responsible for the symptoms.

References


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Commentary

Yamazaki et al. present important data based on their experience with flexion-extension computed tomography (CT) myelography for the study of cervical degenerative disease. In their reported 15...
The authors note in their results that surgical decision-making was based on their dynamic radiological findings considered together with the neurological examinations and MRI data. They imply, as illustrated in their presented case reports, that dynamic imaging information may significantly alter one's surgical approach to a given patient. The authors treated all 6 of their cases of “multi-segmental cord impingement” with laminoplasty. It would be interesting to see data regarding preoperative cervical spine alignment for these patients. This way readers could more clearly assess whether this strategy was truly due to multilevels of posterior canal impingement as defined by dynamic study or rather simply the preservation of normal lordosis in the presence of multisegment cervical disease.

Several studies with dynamic MRI have confirmed extension, rather than flexion, to be more commonly associated with cord impingement seen on dynamic imaging and not on static imaging (refs. 3 and 15 of this article). We wonder whether the authors’ findings were similar: this information is not discussed here. Nevertheless, the 2 case reports they present seem to describe and confirm this phenomenon as well.

We agree that dynamic CT myelography, as described here by Yamazaki and co-workers, is a novel strategy that adds value to patient workup and can favorably alter one’s surgical approach to these cases, and we congratulate them on a beautiful paper and a strategy that adds value to patient workup and can favorably alter the surgical approach to these cases, we usually do not have many problems in making a precise diagnosis and deciding the proper surgical method, keyhole anterior approach with cage fixation vs posterior expansive laminoplasty.

As a patient, it is nice not to have invasive procedures in preoperative work-ups. When the authors develop further experience in surgical management of cervical discogenic disorders, I believe that they will not have to depend on rather invasive CT myelography any more in the near future.

As the authors clearly showed, multi-detector helical CT with high-resolution sagittal reformation definitely provided further refinement in neuroimaging of the cervical spine and completely replaced conventional polytomography. There is no question that a dynamic factor is important in the diagnosis and management of cervical discogenic disorders, and that CT myelography on extension can demonstrate a clear image of increased cord compression. However, CT myelography with intrathecal contrast injection is not by any means a noninvasive procedure, and it should be limited to selected cases with controversial situation.

I myself had a lot of experiences of CT myelography before MRI and in the early stage of MRI with rather poor resolution, but we almost totally abandoned rather invasive myelography and CT myelography except for rare occasions in our institutes and affiliated hospitals ten years ago. With careful neurological examination and with careful neuroimaging study including dynamic X-rays, CT with sagittal reformation and high-resolution MRI with MR myelography, we usually do not have many problems in making a precise diagnosis and deciding the proper surgical method, keyhole anterior approach with cage fixation vs posterior expansive laminoplasty.

As a patient, it is nice not to have invasive procedures in preoperative work-ups. When the authors develop further experience in surgical management of cervical discogenic disorders, I believe that they will not have to depend on rather invasive CT myelography any more in the near future.

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