A Comparison of Angiographic CT and Multisection CT in Lumbar Myelographic Imaging

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AJNR Am J Neuroradiol 2008, 29 (3) 442-446
doi: https://doi.org/10.3174/ajnr.A0853
http://www.ajnr.org/content/29/3/442
Radiographic myelography and postmyelographic CT using multisection CT (MSCT) scanners are well-established diagnostic procedures in degenerative or traumatic lumbar spine disease. Especially when the diagnostic evaluation of the thecal sac and single nerve roots in degenerative spine disease is required, myelography and postmyelographic CT are considered to be even more sensitive and specific than MR imaging or MR myelography. In addition, degenerative osseous changes are better examined by radiography or CT.

From the neuroradiologic point of view, 3D rotational angiography is primarily a technique to visualize intracranial vessels, particularly aneurysms, in a 3D surface-shaded or volume-rendered reconstruction. It has already been demonstrated that 3D rotational myelographic imaging with image intensifier equipped systems is possible and provides multiplanar reconstructed (MPR) images of good quality. In comparison with the image intensifier-equipped systems, the latest flat panel detector–equipped angiographic devices provide a much higher acquisition speed and image information attenuation. These features are combined with a large rectangular field of view. Rotational acquisitions by such detectors provide an almost CT-like contrast resolution allowing a differentiation of objects down to 10 Hounsfield units of attenuation difference. This can be of great importance during neurointerventional procedures. The spatial resolution is higher than in current helical CT: angiographic CT (ACT) provides an isotropic resolution of less than 0.2 mm in comparison with approximately 0.5 mm of minimal CT resolution. The ACT volume dataset (~20 cm width and 25 cm height) can be used for 3D and multiplanar reconstructions in the same fashion as a spiral CT dataset.

The purpose of the study presented here was to test the practicability and the diagnostic features of myelographic section imaging by ACT in comparison with MSCT to verify a possible added diagnostic value of ACT and to provide first evidence about the feasibility of substituting myelographic MSCT with ACT.

**Methods**

**Patients**

Between November 2005 and March 2006, 26 consecutive patients with degenerative lumbar spine disease of different degrees (11 women and 15 men; median age, 61 years; range, 51–74 years) underwent a diagnostic myelography in our department. ACT was additionally performed to obtain images with a very high spatial resolution and to reduce fluoroscopy time by planning radiographic projections on the 3D ACT reconstructions. Approval of the local ethics committee and informed patient consent were obtained.

**Image Acquisition**

Rotational and conventional lumbar myelographies were performed on an AXIOM Artis dBA biplane angiography system equipped with flat panel detectors (Siemens Medical Solutions, Forchheim, Germany). The unit is certified to be used in whole body examinations according to the current ionizing radiation regulations (“CE” mark).
First, intrathecal contrast media application was performed, commonly in between L3 and L4 (15–20 mL of Isovist 300; Schering, Berlin, Germany). In prone position and with breath hold, the rotational acquisitions (1 per patient) were performed with the following parameters: 20 seconds of rotation, 538 projections, 220° total angle (30 cm × 40 cm detector size), and weighted CT dose index at −22 mGy (manufacturer information). On the same system and in prone position, as well, myelograms were acquired in standard projections (anteroposterior, right and left posterior oblique, and lateral). Because the table of the angiographic device can only be tilted to 15°, lateral projections in anteflexion and retroflexion out of the erect position are presented in Table 2 (2 ratings and 3 observers: ACT at 80.6% versus MSCT at 87.8% (Fisher exact test, 2-tailed, P = .091); “perceptibility of intervertebral disks”: ACT at 24.5% versus MSCT at 73.8% (P < .001); “perceptibility of bone structures”: ACT at 78.2% versus MSCT at 88.4% (Fisher exact test, 2-tailed, P = .016); “contrast media distribution”: ACT at 80.6% versus MSCT at 87.8% (P = .091); “perceptibility of intervertebral disks”: ACT at 24.5% versus MSCT at 73.8% (P < .001); “diagnostic applicability”: ACT at 91.9% versus MSCT at 99.4% (P = .001); “delineation of spinal nerve roots,” and “delineation of intervertebral disks.” Film viewing was repeated after a 3-month interval, and the term “diagnostic applicability” was only asked in the second ranking, to allow a familiarization with the different visual impression provided by the ACT. Weighted κ statistics were calculated to assess intraobserver and interobserver variabilities, and a value above ω = 0.60 was assumed to represent substantial agreement.13

Results

Statistical Analysis

Three experienced neuroradiologists (E.E., A.M., H.-H.R.), blinded for the history, clinical symptoms, and acquisition technique, performed the film viewing. They were asked to rate the value of the documented reconstructions according to the following categories in a 5-step ordinal scale (“very good” versus “good” versus “moderate” versus “poor” versus “very poor”): “overall impression,” “contrast media distribution,” “perceptibility of intervertebral disks,” “perceptibility of bone structures,” “delineation of the spinal canal,” “delineation of spinal nerve roots,” and “diagnostic applicability.” Film viewing was repeated after a 3-month interval, and the term “diagnostic applicability” was only asked in the second ranking, to allow a familiarization with the different visual impression provided by the ACT. Weighted κ statistics were calculated to assess intraobserver and interobserver variabilities, and a value above ω = 0.60 was assumed to represent substantial agreement.13

### Table 1: Cumulative results after all ratings

| Variable                        | Very Good, n (%) | Good, n (%) | Moderate, n (%) | Poor, n (%) | Very Poor, n (%) | Total, n (%) |
|---------------------------------|------------------|-------------|-----------------|-------------|------------------|--------------|
| Overall impression              | ACT 46 (28.8)    | 79 (49.4)   | 7 (4.4)         | 27 (16.9)   | 1 (0.6)          | 160 (100)    |
|                                 | MSCT 90 (58.1)   | 47 (30.3)   | 4 (2.6)         | 11 (7.1)    | 3 (1.94)         | 155 (100)    |
| Contrast media distribution     | ACT 49 (30.6)    | 80 (50.0)   | 13 (8.1)        | 18 (11.3)   | 0 (0.0)          | 160 (100)    |
|                                 | MSCT 90 (58.1)   | 46 (29.7)   | 5 (3.2)         | 11 (7.1)    | 3 (1.9)          | 155 (100)    |
| Perceptibility of intervertebral disks | ACT 22 (13.8)  | 17 (10.7)   | 9 (5.7)         | 77 (48.4)   | 35 (22.0)        | 160 (100)    |
|                                 | MSCT 55 (35.3)   | 60 (38.5)   | 15 (9.6)        | 25 (15.0)   | 0 (0.0)          | 155 (100)    |
| Perceptibility of bone structure | ACT 26 (16.3)    | 71 (44.4)   | 10 (6.3)        | 50 (31.3)   | 3 (1.9)          | 160 (100)    |
|                                 | MSCT 117 (74.5)  | 34 (21.9)   | 2 (1.3)         | 2 (1.3)     | 0 (0.0)          | 155 (100)    |
| Delineation of the spinal canal  | ACT 71 (44.4)    | 76 (47.5)   | 3 (1.9)         | 10 (6.3)    | 0 (0.0)          | 160 (100)    |
|                                 | MSCT 128 (82.6)  | 26 (16.8)   | 0 (0.0)         | 1 (0.7)     | 0 (0.0)          | 155 (100)    |
| Delineation of spinal nerve roots| ACT 35 (22.0)    | 60 (37.5)   | 13 (8.1)        | 46 (28.8)   | 6 (3.8)          | 160 (100)    |
|                                 | MSCT 87 (56.1)   | 50 (32.3)   | 8 (5.2)         | 10 (6.5)    | 0 (0.0)          | 155 (100)    |
| Diagnostic applicability        | ACT 30 (19.3)    | 36 (24.4)   | 4 (2.5)         | 10 (6.3)    | 1 (0.6)          | 160 (100)    |
|                                 | MSCT 48 (31.6)   | 28 (35.9)   | 1 (1.3)         | 1 (1.3)     | 0 (0.0)          | 78 (100)     |

Note: ACT indicates angiographic CT; MSCT, multisection CT.

n (%)

### Image Postprocessing

Postprocessing of the rotational image data to a volume dataset (ACT) was performed using dedicated commercial software on a “Leonardo” medical workstation (DynaCT, InSpace 3D; Siemens Medical Solutions). The software includes the application of system-specific filter algorithms to correct for beam hardening, scattered radiation, truncated projections, and ring artifacts. Postprocessing resulted in a volume dataset defined by a batch of 400–500 sections in a 256 × 256 matrix. Single-section thickness was 0.2–0.3 mm (isotropic). Postprocessing in a higher-resolution matrix was performed in some cases but not used for the study because of a limited reconstruction volume size that did not provide coverage of the whole lumbar spine.

For retrospective evaluation ACT and MSCT data were further processed into MPR sections in sagittal and transversal directions: of all of the examinations, 2 stacks of transversal sections (8 sections each; single section thickness, 2 mm) covering 2 lumbar segments, mostly L4/5 and L5/S1, were prepared. A second stack of 4 midsagittal sections was additionally prepared (single section thickness, 2 mm). Window levels were not standardized; a typical window level for ACT was (length/width) 1500/4000 and for MSCT was 1000/2500. The images were anonymized and printed on x-ray films to be viewed under realistic diagnostic conditions.

Statistical Analysis

Both methods achieved predominantly positive results in all of the diagnostic categories evaluated. Table 1 shows the cumulative results of all of the ratings. Total numbers differ a little due to loss of 1 of the pseudonomized films during the first rating session. Combining the categories “very good” and “good” to form the positive side of the test leads to the following results: “overall impression”: ACT at 78.2% versus MSCT at 88.4% (Fisher exact test, 2-tailed, P = .016); “contrast media distribution”: ACT at 80.6% versus MSCT at 87.8% (P = .091); “perceptibility of intervertebral disks”: ACT at 24.5% versus MSCT at 73.8% (P < .001); “perceptibility of bone structure”: ACT at 60.7% versus MSCT at 96.4% (P < .001); “delineation of the spinal canal”: ACT at 91.9% versus MSCT at 99.4% (P = .001); “delineation of spinal nerve roots,” and “diagnostic applicability.”
6, paired; apart from “diagnostic applicability”: n = 3). A substantial level of agreement results in testing each observer against the others for ACT, as well as for MSCT.14 Performing a 2-tailed Student t test (95% confidence interval), a significant difference in agreement only appears in the category “perceptibility of bone structure.” Here, the agreement between the observers is relatively low for the ACT data in comparison with MSCT. In the category “contrast media distribution,” statistical significance is just missed. Here, the level of agreement is much higher for ACT. The χ values obtained for the category “diagnostic applicability” are very similar between the observers (ACT, 0.74 ± 0.06 versus MSCT, 0.75 ± 0.03; P = .8261).

The results of the χ statistics for intraobserver agreement are presented in Table 3. Again, substantial agreement is obtained for both methods in all of the categories.14 Almost perfect agreement emerges for ACT in the category “overall impression.”

### Discussion

This is the first study comparing the diagnostic value of ACT versus MSCT in lumbar myelographic imaging. Single case reports have shown previously that the method itself is feasible and that an acceptable image quality is achievable.6,13 A similar application has already been described in a small case series: an intraoperative C-arm system with capability of rotational acquisition was used for multplanar myelographic imaging during lumbar decompression.15

Both ACT and MSCT yielded predominantly positive or very positive results in all of the diagnostic categories. MSCT as the current “gold standard” was significantly better than ACT in all of the diagnostic categories. Only 80% of all of the ACT examinations were rated as sufficient for diagnosis. The shortcomings in myelographic ACT especially concern the delineation of soft tissue structures. Although it is the main purpose of a myelogram to delineate the thecal sac, the spinal nerve roots, and the adjacent bone, it is the particular interest in myelographic CT to additionally provide information on soft tissue structures like ligaments and intervertebral disks. Here, ACT fails in up to 70% of cases (“perceptibility of intervertebral disks”; Table 1).

Interobserver and intraobserver agreement in the weighted χ statistics were substantially good in all of the categories and for both methods.14–17 The testing of the intraobserver agreement does not reveal any hint for a learning curve regarding ACT images, which would be represented by a lower χ value than that of MSCT.

The primary application of ACT is the imaging of high-contrast structures, such as vessels filled with contrast media.18 In this study we describe a different application by performing an ACT examination after intrathecal administration of contrast media. The 3D information contained in the myelographic ACT datasets can be used for 3D volume-rendered technique (VRT) and 3D maximum intensity projection (MIP) images that compare well with conventional myelography (Fig 1). In addition, using these volume data to plan the myelographic projections could save fluoroscopy time; having performed the rotational acquisition as the very first scan, one can place the C-arm according to the position of the 3D image on the workstation and thereby avoid fluoroscopy. The approximately radiation dosage of 20 mGy per ACT acquisition (manufacturer information) is relatively low compared with an abdominal CT acquisition (40 mGy).19 Phantom measurements of effective patient dosage in lumbar ACT acquisitions have not been available thus far.

However, the higher spatial resolution of ACT in comparison with MSCT did not translate into a diagnostic advantage in our series (Figs 2 and 3). When conducting the examinations, we were expecting a far better delineation of the bone and of a smaller structure, such as the spinal nerve roots. A reason for the relatively poor rankings of ACT in these categories may be the significant amount of ring artifacts, edge artifacts, and scattered radiation-related image noise, which partially antagonized the high spatial resolution and significantly lowered the signal intensity-to-noise ratio. A possible source of movement artifacts may be the patient’s position during the rotational acquisition; like in conventional myelography, the patients were placed in the prone position. Placement in the supine position, as in postmyelographic CT, could serve as a solution.

The technical conditions in our study differ from the first case report on rotational myelography, where an image intensifier-equipped system was used.5 The acquisition protocol that we used is dedicated to achieve a contrast resolution close to conventional CT in combination with high spatial resolution; therefore, the relatively long acquisition time of 20 seconds is necessary. Otherwise we could not expect to discriminate disks and ligaments in a CT-like fashion. Because breath holds for up to 20 seconds are difficult to perform for some patients with lumbago, the duration of the acquisition is a significant drawback, possibly causing substantial movement artifacts. Further technical developments concerning faster digital image acquisition might provide faster protocols in the future.

Our retrospective analysis demonstrates that, in a large amount of patients, the entire diagnostic myelographic examination, including multplanar cross-sectional imaging,
could have been performed at the angiographic device. Concerning efficiency, it may be advantageous to perform conventional myelography and cross-sectional imaging at a single imaging system plus all of the postprocessing on 1 workstation. If this was practiced, an additional postmyelographic MSCT scan could always be performed later on, for example, limited to a certain segment of interest or in question, if the rotational acquisition is not sufficient for diagnosis. An important benefit for the patient would be a substantial amount of time saved and comfort gained by possibly saving the MSCT scan. However, to establish myelographic ACT as a realistic diagnostic alternative to MSCT in diagnostic myelographic imaging, the imaging characteristics of ACT are currently not sufficient.
References

1. Bartynski WS, Lin L. Lumbar root compression in the lateral recess: MR imaging, conventional myelography, and CT myelography comparison with surgical confirmation. AJNR Am J Neuroradiol 2003;24:348–60

2. Bischoff RJ, Rodriguez RP, Gupta K, et al. A comparison of computed tomography–myelography, magnetic resonance imaging, and myelography in the diagnosis of herniated nucleus pulposus and spinal stenosis. J Spinal Disord 1993;6:289–95

3. Saint-Louis LA. Lumbar spinal stenosis assessment with computed tomography, magnetic resonance imaging, and myelography. Clin Orthop Relat Res 2001;122–36

4. Thornton MJ, Lee MJ, Pender S, et al. Evaluation of the role of magnetic resonance imaging in lumbar spine imaging. Eur Radiol 1999;9:924–29

5. Tsuchiya K, Katase S, Aoki C, et al. Application of multi-detector row helical scanning to postmyelographic CT. Eur Radiol 2003;13:1438–43

6. Kufeld M, Claus B, Campi A, et al. Three-dimensional rotational myelography. AJNR Am J Neuroradiol 2003;24:1290–93

7. Zellerhoff M, Scholz B, Ruehrnschopf EP, et al. Visualization of 3D low contrast objects by CT cone-beam reconstruction of a rotational angiography with a dynamic solid body detector [in German]. RoFo 2005;S1:PO 160

8. Cohen J. Weighted kappa: nominal scale agreement with provision for scaled disagreement or partial credit. Psychol Bull 1968;70:213–20

9. Anxionnat R, Bracard S, Macho J, et al. 3D angiography. Clinical interest. First applications in interventional neuroradiology. J Neuroradiol 1998;25:251–62

10. Heran NS, Song JK, Namba K, et al. The utility of DynaCT in neuroendovascular procedures. AJNR Am J Neuroradiol 2006;27:330–32

11. Kalender WA. The use of flat-panel detectors for CT imaging [in German]. Radiologie 2003;43:379–87

12. Loose R, Wucherer M, Brunner T. Visualization of 3D low contrast objects by CT cone-beam reconstruction of a rotational angiography with a dynamic solid body detector [in German]. RoFo 2005;51:PO 160

13. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74

14. Buhk JH, Eloff E, Knauth M. Angiographic computed tomography is comparable to multislice computed tomography in lumbar myelographic imaging. J Comput Assist Tomogr 2006;30:739–41

15. Mauer UM, Kunz U. Intraoperative three-dimensional imaging to monitor selective decompression in lumbar spinal stenosis [in German]. Orthopade 2006;35:1258–60

16. Jakobsson U, Westergren A. Statistical methods for assessing agreement for ordinal data. Stand J Caring Sci 2005;19:427–31

17. Anssonmat R, Bracard S, Macho J, et al. 3D angiography. Clinical interest. First applications in interventional neuroradiology. J Neuroradiol 1998;25:251–62

18. Gray JE, Archer BR, Butler PF, et al. Reference values for diagnostic radiology: application and impact. Radiology 2005;235:354–58

19. Akhtar M, Vakharia KT, Mishell J, et al. Randomized study of the safety and clinical utility of rotational vs. standard coronary angiography using a flat-panel detector. Catheter Cardiovasc Interv 2003;66:43–49

Fig 3. MPR images from a 75-year-old woman with persistent back pain after multisegmental laminectomy. In the sagittal sections (A, ACT; B, MSCT), the relevant degenerative changes can be depicted equally well: ligamental hyperplasia in the segment L1/2, ventral osteochondrosis in the segment L2/3, and the slight listhesis in the segment L4/5. A. Note the loss of detail and the enhanced image noise in the ACT section at the level from L5 to S2 due to the high attenuation of contrast media in the thecal sac. The transverse sections through the vertebral body of L4 (C, ACT; D, MSCT) show the hypertrophic facet joints and the thecal sac herniating into the laminectomy site. Both techniques show a well-defined L4 nerve root of the right side and an increase of tissue around the L4 nerve root of the contralateral side.