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Percutaneous discography: comparison of low-dose CT, fluoroscopy and MRI in the diagnosis of lumbar disc disruption

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Abstract *Aim:* To compare the diagnostic accuracy of low-dose computed tomography (CT), magnetic resonance imaging (MRI) and fluoroscopy in percutaneous discography in patients scheduled for lumbar spondylodesis. *Material and methods:* Within a prospective pilot study, 18 disc segments of 11 patients with radicular or pseudoradicular pain prior to anteroposterior spondylodesis were evaluated. After injection of a mixture of non-ionic iodine-containing contrast agent and gadolinium-based contrast medium into the disc spaces, all patients underwent conventional fluoroscopy, as well as low-dose CT and MRI. The occurrence of memory pain during contrast injection was recorded. CT, MRI and fluoroscopic

images were analyzed independently by two readers blinded to the clinical findings. *Results:* There was 100% agreement between CT and MRI discography in the detection, localization and grading of degenerative changes. In contrast, conventional fluoroscopy identified only 9 of the 12 abnormal segments. Memory pain following puncture was identified in 3 of the 12 affected segments. *Summary:* Low-dose CT and MRI discography have a similar accuracy in the assessment of disc disruption and they are superior to fluoroscopic discography.

Keywords Computed tomography · Low dose · Magnetic resonance imaging · Discography

Introduction

Discography, first described by Lindblom in 1948 [16], used to be a routine diagnostic procedure in which contrast medium is injected into the intervertebral disc after puncture. It has since been largely replaced by magnetic resonance imaging (MRI) in the routine diagnostic setting. The diagnostic value of discography is disputed [1, 3, and 12]. When conducted properly, however, the patient's known pain syndrome can be elicited in the affected segment (memory pain) with additional depiction of the degenerative changes of the intervertebral disc [20]. The routine diagnostic application of discography is limited by its potentially more

severe complications, in particular spondylodiscitis, compared to MRI and computed tomography (CT). However, discography continues to have a role in performing specific diagnostic tasks such as the differentiation of scar tissue and recurrent disc prolapse, resolving discrepancies between clinical and imaging findings, and identification of the level of the lesion prior to surgery [13]. These indications are further corroborated by the fact that morphologic changes demonstrated by MRI and CT do not necessarily correlate with the clinical symptoms [27].

While some authors advocate the sole use of fluoroscopic discography with the elicitation of memory pain to confirm the diagnosis, CT is more and more widely

used to guide needle positioning and identify disc lesions. CT-based discography using a standard-dose protocol [15], however, is associated with a much higher radiation exposure of the patient as compared with fluoroscopy. With the establishment of intradiscal administration of a gadolinium-based contrast medium [11, 15], it has also become technically feasible to perform discography without radiation exposure using MRI [25]. However, MRI-based discography is more time consuming and more expensive than discography by means of CT or fluoroscopy and is rarely used in the routine clinical setting.

The development of techniques aimed at reducing the radiation dose of CT examinations has shown that high-contrast objects such as focal pulmonary lesions, bones, renal calculi, and contrast medium can also be examined with CT protocols with a markedly reduced radiation exposure. To our knowledge, the application of a low-dose protocol for demonstrating segmental instability by CT-based discography has not been described before. Hence, no data is available comparing the diagnostic yield of such a low-dose protocol with that of MRI discography or fluoroscopic discography. The present study was undertaken to compare these three modalities in performing discography.

Materials and methods

Eleven patients (seven women, four men; mean age 42 years) with chronic discopathy confirmed by MRI and scheduled for anteroposterior spondylodesis were included in this prospective pilot study. A total of 18 disc segments were examined, which were localized above or below the disc segments already predetermined for spondylodesis due to conclusive clinical and MRI findings. All examined disc segments demonstrated slighter or stronger chronic degenerative changes on plain MRI. All discs presented with a decrease of signal intensity on T2 images, six segments showed endplate changes, and four segments appear with disc protrusion. Written informed consent was obtained from all patients prior to the examination.

The patients were positioned prone on the table of the CT scanner with a cushion placed under the lumbar area to straighten out the curvature of the lumbar spine. A fluoroscopic view was obtained in the lateral projection on the basis of which a single CT scan was acquired at the intervertebral disc level of each segment investigated. These scans served to plan the puncture trajectory. Next, the skin was carefully disinfected and 5–10 ml of 0.1% lidocaine was applied for local anesthesia of the cutaneous and subcutaneous layers. Following these preparations, a 0.8 mm fine needle was advanced to the intervertebral disc and the nucleus pulposus punctured from a lateroposterior

direction under CT and fluoroscopic guidance. The needle was always inserted from the less symptomatic side.

Following documentation of the needle position, a mixture of 0.5 ml iodine-based contrast medium (Ultravist 320, Schering, Berlin, Germany), 0.01 ml gadolinium-based contrast medium (Magnevist, Schering), and 1.0 ml sodium chloride solution was slowly injected into the nucleus pulposus at a maximum dose of 0.8 ml. The occurrence of memory pain was recorded followed by acquisition of an X-ray fluoroscopic image in lateral projection with a standard mobile C-arch (Exposcop CB7D, Ziehm, Nürnberg, Germany) installed directly adjacent to the CT gantry.

The subsequent CT examinations were performed on a single-slice helical CT scanner (Philips, Eindhoven, The Netherlands). Scanning was done at 120 kV and a reduced tube current of 25 mA. To further reduce the radiation exposure, no complete helical scans were acquired but only individual incremental slices. A mean of 33 slices with a thickness of 3 mm were acquired per patient (SD of 13 slices), corresponding to 18 slices per segment examined, during and after injection of the contrast medium. The rotation time was 1 s. All images thus generated were analyzed digitally on a viewing station (View Forum, Philips, Eindhoven, The Netherlands) and archived. The radiation exposure was calculated using CT-EXPO V.1.3 [26].

Following visualization by fluoroscopy and CT, the needle was removed and the patients underwent an additional MRI examination of the affected segments.

All patients were studied in a 1.5 T MRI scanner (Magnetom Vision, Siemens, Erlangen, Germany). T1 spin echo sagittal (TR700 and TE10, slice thickness 4 mm, matrix 412×435, FOV 280 mm, four acquisitions) and T1 spin echo axial (TR700–950—depending on the numbers of slices acquired—and TE10, slice thickness 4 mm, matrix 412×435, FOV 230 mm, four acquisitions) scans of the lumbar spine were obtained.

The interval between CT and MRI was 10–25 min, during which the patients were turned and remained in a supine position.

The CT and MRI data sets, as well as the fluoroscopic images were analyzed separately by two experienced radiologists blinded to the results of the other imaging modalities and the clinical findings except of the puncture side. The readers rated the severity of disc degeneration (none, mild, moderate, or pronounced) and noted if an annular tear was present. In addition, contrast medium leakage was recorded and, where present, the site of the underlying tear noted (posteromedial, posterior paramedian, posterolateral, lateral, anterolateral, anterior paramedian, and anteromedial). Unilateral contrast medium leakage demonstrated by MRI on the side of the puncture was not interpreted as disc degeneration but as leakage into the puncture canal

Table 1 Radiation exposure of the low-dose CT discography protocol in comparison with data reported in the literature

References	Examination	Protocol	Whole body dose
Present study	Low-dose CT discography	120 kV 25 mA	0.7–0.8 mSv
Falco and Moran [11]	CT discography	130 kV 200 mA	Not provided
Huang et al. [15]	CT discography	120 kV 180 mA	Not provided
Mini [18]	X-ray of the lumbar spine	pa and lateral projection	0.8 mSv
Calzado et al. [4]	CT of the lumbar spine	120 kV different tube current	3–5 mSv
Cohnen et al. [7]	CT of the lumbar spine	140 kV 130 mA	10.5–12 mSv

(Fig. 1). Such leakage was not demonstrated by CT or fluoroscopy, which was performed with the needle in place.

The sensitivity and specificity of low-dose CT and fluoroscopy were determined using MRI as the standard of reference.

Results

The mean effective whole-body dose of the low-dose CT protocol was 0.9 mSv for women and 0.8 mSv for men

with a gonadal dose of 0.7 mSv in women. This radiation exposure of the low-dose protocol corresponds to about 10% of the exposure of a standard-dose CT scanning protocol. A comparison of the radiation exposure of the low-dose protocol used here with data reported in the literature is presented in Table 1.

In all patients examined, there was complete agreement between low-dose CT and the reference standard, MRI, in terms of presence, localization, and type of lesion identified (Fig. 1, 2). Of the 18 segments examined, four were normal and 14 showed abnormalities with both modalities (Table 2). The lesions were rated as mild

Fig. 1 A 53-year-old patient with chronic lumbar pain predominantly of the left side prior to spondylodesis of L4-S1. Both CT discography (a) and post-interventional MRI (b, c), as well as conventional fluoroscopy (d) demonstrate a normal L3/L4 segment. The contrast medium leak at MRI (arrow) is interpreted to indicate the puncture tract

Fig. 2 A 49-year-old patient with pseudoradicular pain syndrome mainly on the right. Agreement between low-dose CT (a) and MRI (b). CT- and MR-discography demonstrates a wide tear with posteromedial leak of contrast medium. Conventional fluoroscopy demonstrates no leak of contrast medium (c)

on both CT and MRI in two cases and as moderate to severe in 12 cases showing degenerative changes of the disc compartment with leakage of contrast medium from a tear of the annulus fibrosus. The low-dose CT protocol

thus has a sensitivity of 100% compared to MRI in demonstrating lesions of the disc spaces. In contrast, fluoroscopy in lateral projection identified the pathology in only 9 of 12 cases, resulting in a sensitivity of 75% for

Table 2 Comparison of fluoroscopy, CT and MRI findings

Patient	Sex	Age	Disc	MRI	CT	Fluoroscopy	Memory pain
1	F	31	L3/4	No leakage	Normal	Normal	No pain
			L4/5	Posteromedial tear, leak of CM	Posteromedial tear, leak of CM	Leak of CM	No pain
2	M	40	L2/3	Right anterior tear, leak of CM	Right anterior tear, leak of CM	Normal	No pain
			L3/4	Left posterolateral tear, leak of CM	Left posterolateral tear, leak of CM	Leak of CM	Memory pain
3	F	41	L3/4	Posteromedial tear, leak of CM	Posteromedial tear, leak of CM	Normal	No pain
			L4/5	Posteromedial tear, leak of CM	Posteromedial tear, leak of CM	Leak of CM	No pain
4	F	60	L3/4	Left posterolateral tear, leak of CM	Left posterolateral tear, leak of CM	Normal	No pain
			L5/S1	Right posterolateral tear, leak of CM	Right posterolateral tear, leak of CM	Leak of CM	No pain
5	F	20	L4/5	Posteromedial tear, leak of CM	Posteromedial tear, leak of CM	Leak of CM	Memory pain
6	M	53	L3/4	Normal	Normal	Normal	No pain
7	M	38	L4/5	Normal	Normal	Normal	No pain
8	F	55	L3/4	Normal	Normal	Normal	No pain
			L4/5	Posteromedial tear, leak of CM	Posteromedial tear, leak of CM	Leak of CM	No pain
9	M	48	L3/4	Posteromedial tear, leak of CM	Posteromedial tear, leak of CM	Normal	No pain
			L4/5	Posteromedial tear, leak of CM	Posteromedial tear, leak of CM	Normal	No pain
10	F	31	L4/5	No leakage	Normal	Normal	No pain
11	F	48	L3/4	Normal	Normal	Normal	No pain
			L5/S1	Right posterolateral tear, leak of CM	Right posterolateral tear, leak of CM	Leak of CM	Memory pain

M, F male, female; L, S lumbar, sacral; CM contrast medium

conventional discography using fluoroscopy only. Neither of the two techniques yielded false-positive findings. Both thus had a specificity of 100%. There was no memory pain during puncture of the segments without degenerative lesions or only mild degenerative lesions. However, contrast injection provoked memory pain in 3 of 12 cases with a tear of the annulus fibrosus. Hence, elicitation of the pain syndrome in the clinical situation had a sensitivity of 25% and a specificity of 100% in our patient population. Thus, the provocation of memory pain alone did not change the indication for surgery, but was taken into account as a further certification of MRI and CT findings. The absence of memory pain, e.g., in combination with young age and absence of degenerative changes of the facet joints led to flexible spondylodesis rather than to antero-posterior spinal fusion.

While CT and MRI showed good agreement in the demonstration of abnormal lesions, MRI visualized the lesions with a better spatial resolution and had a higher soft-tissue contrast, which enabled the reliable differentiation of nerve structures, the dural space, and intervertebral disc structures in all segments investigated. Conversely, the low-dose CT protocol enabled reliable identification of the nerve roots in only 14 of the 18 segments (Fig. 3).

The postinterventional MRI examination additionally yielded sagittal and coronal views, which could not be obtained with the CT protocol due to single-slice acquisition instead of helical scanning.

None of the patients developed complications after the intervention. All patients, except one who refused further inpatient treatment, underwent anteroposterior spondylodesis.

Discussion

Chronic degenerative changes of the intervertebral discs that may be associated with a loss of fluid and proteoglycans and a decreasing elasticity of the nucleus fibrosus, finally resulting in a tear of the annulus fibrosus [10], are the most common cause of somatic back pain. In contrast to acute disc prolapse with radicular pain, segmental instabilities occurring on the basis of such chronic degenerative changes of the discs are associated with somatotropic or pseudoradicular pain projection [14]. Therefore, it may be difficult to precisely identify the level of the lesion on the basis of clinical examination alone. MRI is an imaging modality that enables reliable identification of early degenerative changes [22] but a definitive association between the morphologic changes demonstrated by MRI and the clinical symptoms of discopathy has not been established [8, 27]. MRI demonstrates degenerative changes in healthy subjects as well. Patients with chronic lumbar pain often have similar degenerative lesions in clinically symptomatic

and non-symptomatic segments alike. CT scans with or without intravenous contrast medium administration is clearly inferior to MRI in diagnosing degenerative changes of the intervertebral discs. For these reasons, discography continues to have a role in patients with inconclusive clinical and imaging findings, in determining the level of a lesion prior to surgery (nucleotomy, spondylodesis), and in differentiating scar tissue from recurrent disc prolapse [2, 13, 17, and 21].

Some investigators advocate discography under fluoroscopy without use of an additional imaging modality while others recommend CT for puncture and evaluation of disc lesions. Both of these modalities involve radiation exposure to the pelvis and gonads. The exposure associated with CT is much higher, as compared with X-ray fluoroscopy when performed using a standard-dose CT protocol (see Table 1) [4, 7, 18, and 28] but has a sensitivity of about 97% and is thus clearly superior to fluoroscopic discography.

MRI-guided discography followed by a postinterventional MRI examination has the advantage of involving no radiation exposure at all but is more time consuming and expensive. It is rarely used in the routine clinical setting although its diagnostic validity seems to have been verified by now [15].

Our results suggest that abnormal changes of the intervertebral disc can be demonstrated by means of low-dose CT discography at only about 10% of the radiation exposure of a standard-dose CT scan of the lumbar spine with the same degree of accuracy as with postinterventional MRI. In our study, low-dose CT correctly diagnosed six normal and slightly degenerative discs, as well as 12 abnormal disc segments. Thus, the low-dose protocol is comparable to literature data of standard-dose CT protocols in terms of sensitivity and specificity [17]. The sensitivity and specificity of conventional fluoroscopic discography achieved in our study are comparable to values reported in the literature [17], suggesting that the superiority of low-dose CT is not falsified by poor image quality of X-ray fluoroscopy.

Nevertheless, MRI discography has some advantages such as the option of acquiring additional coronal and sagittal views and the better soft-tissue contrast with easier identification of nerve structures. Nerve roots are not visualized at all by conventional fluoroscopy and are poorly visualized on low-dose CT scans due to the lower soft-tissue contrast and reduced signal-to-noise ratio.

One limitation of the present study was that no plain T1 and T2 spin echo sequences were acquired during MRI examinations. We, therefore, did not use a method of grading the severity of end-plate changes as described by Modic et al. [19], which is known to increase the accuracy for identification of painful discs. As a result, the study does not allow suitable comparison of the diagnostic impact of plain MRI with the MRI discography.

Fig. 3 A 41-year-old patient with sensorimotor radicular syndrome, S1, on the right. Prior to contrast medium injection into the disc space of L3/4 (**a**), there is good delineation of the L3 nerve roots on both sides. Following CM administration, both CT discography (**b**) and MRI (**c, d**) show leakage of the contrast medium. Leakage can easily be missed by conventional fluoroscopy (**e**)

Furthermore, results may be limited by the time delay between low-dose CT, fluoroscopy and the gold standard, as well as by transport to the our MRI division. It is hence, theoretically conceivable that the results of MRI are falsified by removal of the needle, patients' motion and consecutive alterations of contrast agent localization.

An alternative study protocol overcoming these limitations would be to determine the accuracy of the low-dose CT discography in comparison with a subsequently

conducted CT discography at the standard dose but this would involve an additional radiation exposure of about 5–10 mSv.

The complication rate of discography ranges from 0.15 to 2.7% for lumbar discography up to 13% for cervical discography [9, 23]. Some authors report that discography with puncture of a healthy intervertebral disc may trigger a protracted back pain syndrome [5, 6, 23], which can be considered as minor complication of

discography, even if demanding for additive psychological and social individual factors [5]. The most serious complication of discography, which is the risk of discitis, is rare [28]. Additionally, the already low incidence can be further reduced by the intradiscal use of prophylactic antibiotics [24].

None of the patients included in our study had any complications immediately after the intervention. However, possible later complications may have escaped detection, as no clinical follow-up over a longer period was performed.

In summary, the diagnostic accuracy of CT-guided low-dose discography with only about 10% of the radiation exposure of a standard-dose CT protocol seems to be similar to that of MRI-based discography in identifying segmental degeneration and appears superior to conventional fluoroscopy. Nevertheless, MRI-based discography not involving any radiation exposure continues to be a valuable alternative modality, especially in younger patients.

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