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Diagnostic performance of direct traction MR arthrography of the hip: detection of chondral and labral lesions with arthroscopic comparison

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Abstract
Objectives To assess diagnostic performance of traction MR arthrography of the hip in detection and grading of chondral and labral lesions with arthroscopic comparison.
Methods Seventy-five MR arthrograms obtained ± traction of 73 consecutive patients (mean age, 34.5 years; range, 14–54 years) who underwent arthroscopy were included. Traction technique included weight-adapted traction (15–23 kg), a supporting plate for the contralateral leg, and intra-articular injection of 18–27 ml (local anaesthetic and contrast agent). Patients reported on neuropraxia and on pain. Two blinded readers independently assessed femoroacetabular cartilage and labrum lesions which were correlated with arthroscopy. Interobserver agreement was calculated using κ values. Joint distraction ± traction was evaluated in consensus.
Results No procedure had to be stopped. There were no cases of neuropraxia. Accuracy for detection of labral lesions was 92 %/93 %, 91 %/83 % for acetabular lesions, and 92 %/88 % for femoral cartilage lesions for reader 1/reader 2, respectively. Interobserver agreement was moderate (κ=0.58) for grading of labrum lesions and substantial (κ=0.7, κ=0.68) for grading of acetabular and femoral cartilage lesions. Joint distraction was achieved in 72/75 and 14/75 hips with/without traction, respectively.
Conclusion Traction MR arthrography safely enabled accurate detection and grading of labral and chondral lesions.
Key Points
• *The used traction technique was well tolerated by most patients.*
• *The used traction technique almost consistently achieved separation of cartilage layers.*
• *Traction MR arthrography enabled accurate detection of chondral and labral lesions.*

Keywords MRI · Arthrography · Traction · Hip joint · Chondral/labral lesions

Abbreviations

FAI	femoroacetabular impingement
FLASH	fast low-angle shot
FISP	fast imaging with steady-state precession
LCEA	lateral centre edge angle

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Introduction

Imaging of the central compartment of the hip which includes the labral-chondral interface, articular cartilage layers, and the ligamentum teres is a radiologic challenge [1]. Direct MR arthrography improved the diagnostic accuracy in detection of labral tears compared to native MRI, but there is still room for improvement regarding its low specificity [2] and the definition of reliable imaging criteria [3]. MR imaging of the gradual loss of articular cartilage or cartilage delamination remains difficult with intra-articular contrast administration [4, 5]. Restricted visualization of articular cartilage layers as

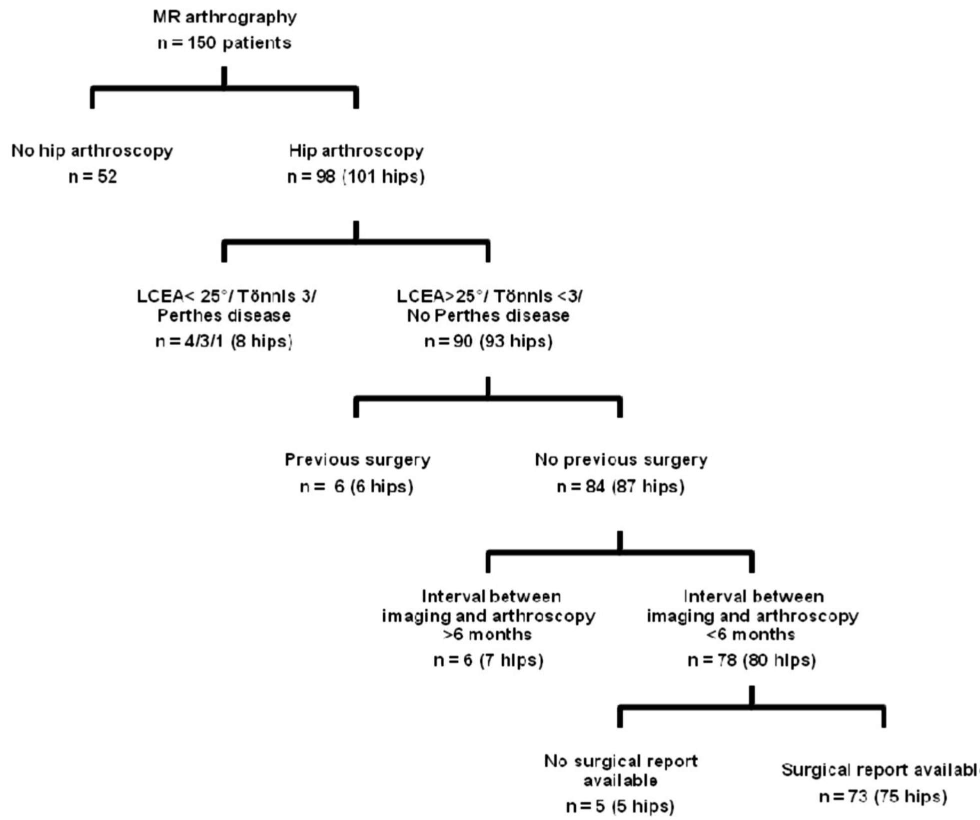

Fig. 1 Flow chart of inclusion and exclusion criteria

two distinct layers is a substantial problem inherent to conventional direct MR arthrography. Hence, the application of axial leg traction during MR arthrography was proposed [5, 6]. It has been shown that application of traction using different techniques is technically feasible, but neither technique has been validated with arthroscopy [6, 7].

Thus, the aim of this study was to assess the diagnostic performance of traction MR arthrography of the hip in detection and grading of chondral and labral lesions with arthroscopic comparison.

Material & methods

Patients

This retrospective study was conducted with approval of the institutional review board and a waiver for informed consent. During a period of 10 months (July 2012 – May 2013) 150 consecutive patients with symptoms suggestive for FAI underwent MR arthrography according to the institutional routine protocol. Inclusion criteria were subsequent arthroscopy at the institution. Exclusion criteria were osteoarthritis grade 3 according to the Tönnis classification (Tönnis 0= no signs of osteoarthritis; Tönnis 1= slight narrowing of joint space, slight femoral/acetabular sclerosis; Tönnis 2= small cysts, increasing narrowing of joint space; Tönnis 3= large cysts, severe narrowing of joint space [8]), LCEA <25°, Perthes disease, previous surgery, interval>6 months between imaging and arthroscopy, and no arthroscopic report of labrum and articular cartilage due to limited arthroscopic accessibility of the central compartment.

Ninety-eight subjects (101 hips) underwent subsequent arthroscopy for treatment of FAI. After exclusion, 75 MR arthrograms of 73 patients remained in the study group (Fig. 1). The study group (mean age, 34.5 years; range, 14–54 years) included 45 men (mean age, 34.2 years; range, 14–53 years) and 28 women (mean age, 35 years; range, 16–54 years). Mean interval between MR arthrography and arthroscopy was 14 weeks (range, 1–26 weeks).

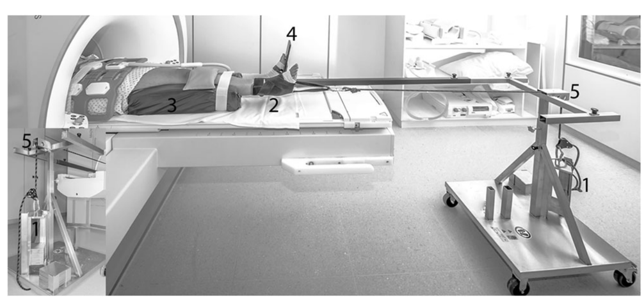

Fig. 2 Distraction of right hip with 23 kg of weight load (1). Fixation with an ankle brace (2) which is connected to the traction device and positioning of the splint (3) for stabilization of the affected extremity. The supporting plate (4) avoids tilting of the pelvis. Traction force is transmitted via a pulley (5) and a cable winch

Table 1 MR arthrography sequencing parameters

Sequence	Repetition Time (ms)	Echo Time (ms)	Matrix	Field of View (mm)	Flip Angle	Section Thickness (mm)	Intersection Gap (mm)	Bandwidth (Hz/Px)	Traction
Coronal FLASH T1-w FS	475	9.8	448×224	180	60	3	0.6	70	no
Axial-oblique FLASH T1-w FS	524	9.8	448×224	180	60	3	0.6	70	yes
Axial-oblique 3D true FISP	4.66	2	256×256×256	200	70	0.8	0.016	501	yes
Sagital FLASH T1-w FS	475	9.8	448×224	180	60	3	0.6	70	yes
Coronal spin echo T1-w	450	12	448×224	180	90	3	0.6	130	yes
Coronal FLASH T1-w FS	475	9.8	448×224	180	60	3	0.6	70	yes

Note: *FS* = fat suppressed, *FLASH* = fast low angle shot, *FISP* = fast imaging with steady-state processing, *T1-w* = T1-weighted

Traction MR arthrography

The used technique for traction MR arthrography was previously described in the literature [7]. Intra-articular injection was performed anterolaterally, under sterile conditions and under fluoroscopic guidance with a 21 G needle. The affected hip was flexed to 5–10 degrees. The injected volume contained 18–27 ml (2–5 ml of local anaesthetic [ropivacaine hydrochloride; 2 mg/mL; Ropinaest; Gebro Pharma, Fieberbrunn, Austria], 1–2 ml of iodinated contrast agent [iopamidol, 200 mg/mL; Iopamiro 200; Bracco, Milan, Italy], 15–20 ml of diluted MR contrast agent [gadopentetate dimeglumine, 2 mmol/L; Magnevist; Bayer Healthcare, Berlin, Germany]). A 1.5 T scanner (Magnetom Symphony; Siemens Medical Solutions, Erlangen, Germany) and large flexible coils were used. An MR-compatible traction device (TRACView; Menges Medical, Gallspach, Austria) was used which consists of a pulley, a cable connected to a weight, and a supporting plate for the contralateral leg. The affected leg was put into a positioning splint and was connected to the traction device with an ankle brace. Traction load was adapted to the patient's body weight. Fifteen kilograms was used for patients who weighed<60 kg. Eighteen kilograms was used for patients who weighed 60–80 kg. Twenty-three kilograms was used for patients who weighed>80 kg. The contralateral leg was stabilized with the foot positioned at the supporting plate to avoid tilting of the pelvis (Fig. 2). The imaging protocol is given in Table 1. MRI under leg traction lasted 19 min.

Table 2 Modified MAHORN classification for grading of labrum and cartilage lesions

Lesion		Illustration	Hip Arthroscopy	MR Arthrography
Labral-chondral separation		*Illustration* 1	cleft located at the chondrolabral interface	focal area of high signal intensity located at the chondrolabral interface
Partial labral tear		*Illustration* 2	cleft extending between labral base and acetabular rim	hyperintense signal extending between labral base and acetabular rim
Complete labral tear		*Illustration* 3	complete labral avulsion from the acetabulum	complete interposition of hyperintense signal between labral base and acetabular rim
Intrasubstance labral tear		*Illustration* 4	radial/longitudinal cleft within labral substance	focal area of hyperintense signal extending into labral surface
Complex labral tear		*Illustration* 5	intersubstance (partial/complete tear) and intrasubstance tear	
Full-thickness cartilage lesions	Bubble	*Illustration* 6	cartilage detached from subchondral bone but intact surface; "carpet phenomenon"	subchondral line of hyperintense signal with intact cartilage surface
	Delamination tear	*Illustration* 7	cartilage delamination with disrupted surface, palpable free edge of cartilage	subchondral line of hyperintense signal with disrupted cartilage surface
	Defect	*Illustration* 8	complete loss of cartilage thickness	complete loss of cartilage thickness
Partial-thickness cartilage lesions	<50 %	*Illustration* 9	cartilage lesion involving <50 % cartilage thickness	cartilage lesion involving <50 % cartilage thickness
	>50 %	*Illustration* 10	cartilage lesion involving >50 % cartilage thickness	cartilage lesion involving >50 % cartilage thickness

Patients were instructed to terminate the examination at any time if needed. They were instructed to report on neuropraxia and on experienced pain during injection, during MR examination, and after 24 h, respectively. For pain assessment, a score of 0 (no pain) to 10 (unbearable pain) was used.

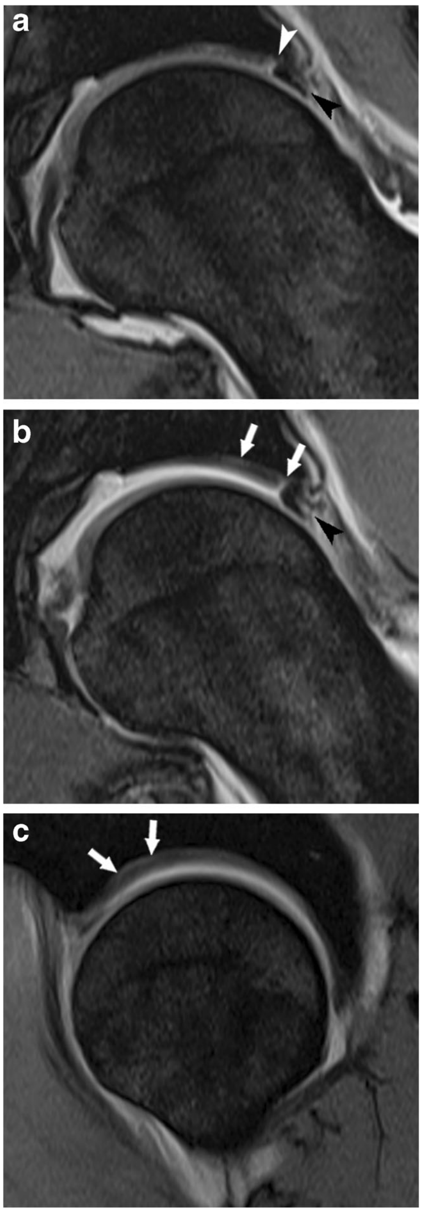

Fig. 3 Forty-three-year-old man with cam type FAI (**a**-**c**). Coronal T1-weighted fat-suppressed FLASH MR arthrogram (repetition time [TR], 475 ms; echo time [TE], 9.8 ms; flip angle, 60) (**a**) Without traction cartilage layers could not be differentiated, but complex tear (*black and white arrowheads*) is detectable. Coronal T1-weighted fat-suppressed traction MR arthrogram (TR, 475 ms; TE, 9.8 ms; flip angle, 60) (**b**) With traction cartilage layers could be differentiated. Both readers detected delamination tear of the acetabular cartilage (*white arrows*) and dislocation of intrasubstance labrum component of the complex labral tear (*black arrowhead*). Sagittal T1-weighted fat-suppressed traction MR arthrogram (TR, 475 ms; TE, 9.8 ms; flip angle, 60) (**c**) A hyperintense line deep to the acetabular cartilage layers is visible (*white arrows*)

Arthroscopic hip surgery

All arthroscopies were performed by two orthopaedic surgeons with 5 years total of experience in hip arthroscopy. A modified version of the arthroscopic MAHORN classification was used for grading of chondral and labral lesions at the time of surgery [9, 10] (Table 2). Localization of acetabular cartilage and labrum lesions was documented as being located anteriosuperiorly, anterioinferiorly, posteriosuperiorly, and posterioinferiorly using a clockface scale [3]. Localization of femoral cartilage lesions was described as anterior or posterior. If more than one lesion was present in the joint the severest damage was documented and used for grading. These classification and localization criteria were used in the initial surgical documentation.

Review of MR arthrograms

Chondral and labral lesions were retrospectively assessed independently by two radiologists with 12 and 5 years of

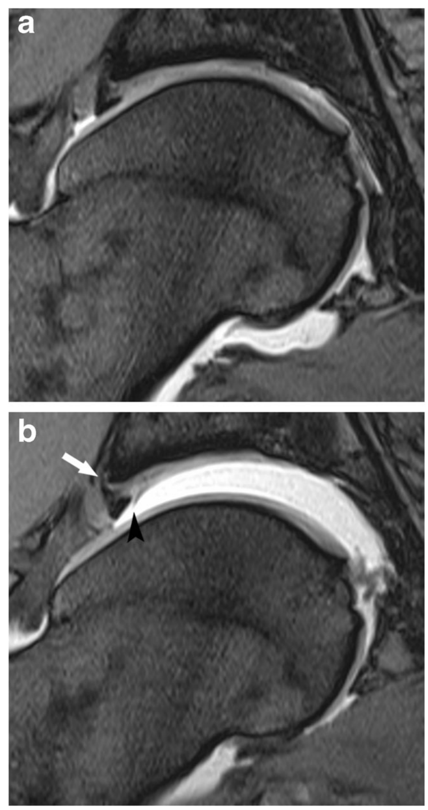

Fig. 4 Thirty-eight-year-old man with mixed type FAI (**a**-**b**). Coronal T1-weighted fat-suppressed MR arthrogram (TR, 475 ms; TE, 9.8 ms; flip angle, 60) (**a**) Without traction cartilage layers could not be differentiated. Coronal T1-weighted fat-suppressed traction MR arthrogram (TR, 475 ms; TE, 9.8 ms; flip angle, 60) (**b**) With traction cartilage layers could be differentiated. Both readers detected confirmed partial labral tear (*white arrow*) and hyperintense signal undermining chondral flap (*black arrowhead*) corresponding to an arthroscopically proven delamination tear

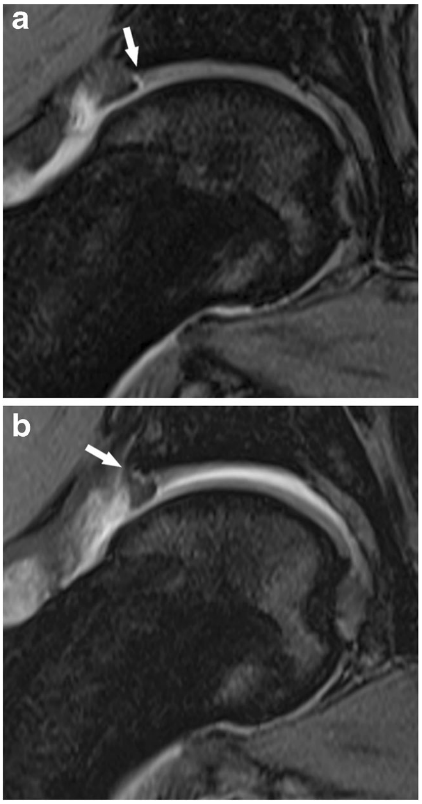

Fig. 5 Twenty-nine-year-old woman with mixed type FAI (**a**-**b**). Coronal T1-weighted fat-suppressed MR arthrogram (TR, 475 ms; TE, 9.8 ms; flip angle, 60) (**a**) Without traction cartilage layers were not seen as distinct entities, but labral-chondral separation is detectable (*white arrow*). Coronal T1-weighted fat-suppressed traction MR arthrogram (TR, 475 ms; TE, 9.8 ms; flip angle, 60) (**b**) Traction enabled differentiation of intact articular cartilage. Both readers detected hyperintense signal extending between labrum and acetabular rim (*white arrow*) corresponding to proven partial labrum tear

experience in musculoskeletal radiology and who were blinded to the arthroscopic records and to the original interpretations. Only traction sequences were used for assessment of labral and chondral lesions. The same classification as for arthroscopy, adopted for MR, was used to grade labral and chondral lesions (Table 2). Localization of cartilage and labrum lesions was documented in accordance to arthroscopy. The 6 o'clock position was set at the midpoint of the transverse ligament [3]. If more than one lesion was present in the joint, the severest damage was documented and used for grading. Cartilage delamination had to be detectable on two planes. In a second assessment both readers evaluated in

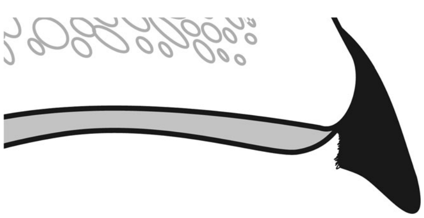

Illustration 1 Labral-chondral separation

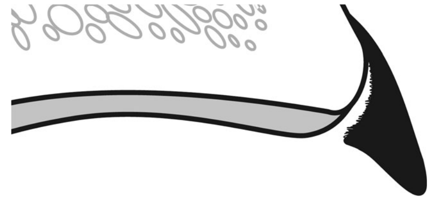

Illustration 2 Partial labral tear

consensus whether articular cartilage layers could be differentiated on coronal images obtained with and without traction (Figs. 3, 4 and 5) (Illustrations 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10).

Statistical analysis

For sensitivity, specificity, positive predicative value, negative predicative value, and accuracy of traction MR arthrography, each with arthroscopy as reference, exact 95 % Clopper-Pearson confidence intervals were calculated. Labral-chondral separation, partial tears, complete tears, intrasubstance tears, and complex tears were defined as abnormal. Loss of less respectively more than 50 % of cartilage thickness, bubble lesions, delamination tears, and cartilage defects were defined as abnormal. Cohen's Kappa with 95 % confidence intervals was calculated to assess inter-rater agreement between radiologists [11–13]: 0, poor agreement; 0.01–0.20, slight agreement; 0.21–0.40, fair agreement; 0.41–0.60 moderate agreement; 0.61–0.80, substantial agreement; 0.81–1.00 excellent agreement. No adjustment for the type I error was made. Hence, confidence intervals and p values are only descriptive. Agreement within one grade was calculated for both readers. This was defined as proportion of arthroscopically confirmed lesions which were graded identically with traction MR arthrography and arthroscopy. Statistical analysis was performed by a biostatistician using the statistical computing software R Version 3.0.2 (R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org).

Results

Traction MR arthrography

No patient asked for termination of the MR examination and no cases of neuropraxia were reported. Seventy-one (71/75=

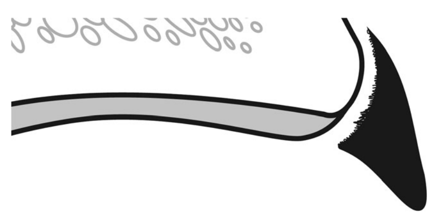

Illustration 3 Complete labral tear

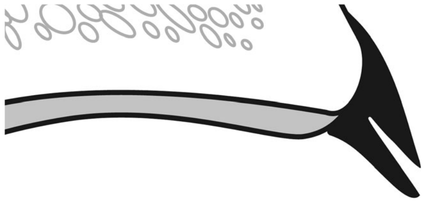

Illustration 4 Intrasubstance labral tear

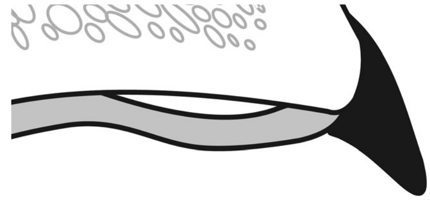

Illustration 6 Full-thickness cartilage lesion: Bubble

95 %; median pain 3; range, 1–9) patients reported on pain during injection. Fifty (50/75=67 %; median pain 2; range 1–8) patients reported on pain during MR imaging. Seven (7/75=9 %; median pain 1; range 1–5) patients reported on pain on the following day. Femoral and acetabular cartilage layers could be seen as distinct entities in 72 (72/75=96 %) cases with traction and in 14 (14/75=19 %) cases without traction.

Arthroscopic hip surgery

At arthroscopy 68 labral lesions and 73 chondral (52 acetabular cartilage lesions, 21 femoral cartilage) lesions were identified in 75 hips. Four hips (5 %) did not have any cartilage or labrum lesions. Combined labral and chondral damage was present in 52 (69 %) cases. Labral defects were restricted to one quadrant in 46 hips (68 %) and were distributed as follows: 43 (94 %) anteriosuperior lesions, two (4 %) anterioinferior lesions, one (2 %) posteriosuperior lesions. Twenty-two (32 %) lesions extended over two quadrants: 10 (46 %) lesions were located in the anteriosuperior and anteriorinferior quadrants; 12 (55 %) lesions were located in anteriosuperior and posteriosuperior quadrants. Acetabular cartilage lesions were restricted to one quadrant in 39 (75 %) cases and were distributed as follows: 38 (97 %) anteriosuperior lesions, one (3 %) posteriosuperior lesion, respectively. Thirteen (25 %) acetabular cartilage lesions extended over the anteriosuperior and posteriosuperior quadrant. Femoral cartilage lesions were distributed as follows: nine (43 %) anterior and nine (43 %) posterior lesions; three (14 %) femoral cartilage lesions were located anteriorly and posteriorly.

Diagnostic performance of traction MR arthrography

Accuracy of traction MR arthrography was 92 % for reader 1 and 93 % for reader 2 in detection of labrum lesions. Accuracy of traction MR arthrography was 91 % for reader 1 and 83 % for reader 2 in detection in acetabular cartilage lesions. Accuracy of traction MR arthrography was 92 % for reader 1 and 88 % for reader 2 in detection of femoral cartilage lesions. Results are summarized in Table 3.

Interobserver agreement between readers 1 and 2 was moderate (κ=0.58, 95 % CI [0.44–0.73], $p<0.001$) in the grading of labral integrity. Substantial (κ=0.7, 95 % CI [0.56–0.83], $p<0.001$; κ=0.68, 95 % CI [0.52–0.84], $p<0.001$) agreement was achieved for characterization of acetabular respectively femoral cartilage layers between readers 1 and 2.

Concordance between arthroscopic and MR gradings is illustrated in Table 4. Agreement of traction MR arthrography with arthroscopy within one grade for labrum lesions was 65 % (44/68) for reader 1 and reader 2. Agreement of traction MR arthrography with arthroscopy within one grade for acetabular cartilage lesions was 75 % (39/52) for reader 1 and 65 % (34/52) for reader 2. Agreement of traction MR arthrography with arthroscopy within one grade for femoral cartilage lesions was 67 % (14/21) for both readers.

Discussion

To best of the authors' knowledge this is the first study which assessed the diagnostic performance of traction MR arthrography. The used technique [7] is different from the one which was described by Llopis and colleagues [6] who applied 6 kg of traction force regardless of the patient's constitution. More weight (15–23 kg) which was adapted to the patient's constitution and a supporting plate to avoid pelvic tilt, as proposed previously [14], was used in the current study. Patients with LCEA<25° were excluded from the study because there was no standardized traction protocol for patients with dysplasia of the hip at the time of the MR examination.

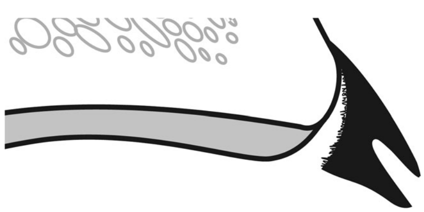

Illustration 5 Complex labral tear

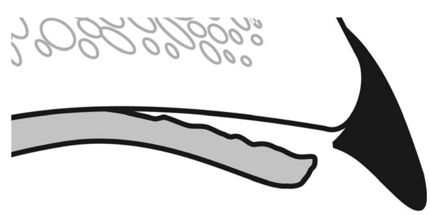

Illustration 7 Full-thickness cartilage lesion: Delamination tear

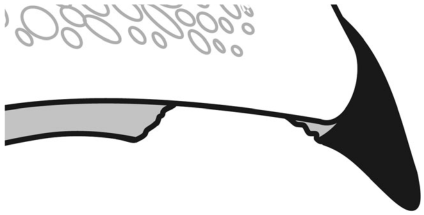

Illustration 8 Full-thickness cartilage lesion: Defect

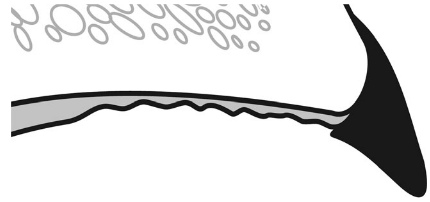

Illustration 10 Partial-thickness cartilage lesion: >50 %

Status of cartilage degeneration determines postoperative outcome after hip arthroscopy [15]. Therefore, preoperative imaging should facilitate proper patient selection and treatment. The goal was to present the diagnostic performance of traction MR arthrography in patients with early stages of joint degeneration which are often difficult to detect with conventional MR arthrography [1]. Hence, patients with osteoarthritis (Tönnis grade 3) were excluded from the study.

Most patients reported transient pain which resolved completely after 24 h. There were no cases of neuropraxia. These findings are in accordance with a previous investigation on traction MR arthrography of the hip [7].

In their study with 1,085 patients who underwent direct MR arthrography, Saupe and colleagues [16] showed that the pain experienced did not depend on the volume of injected contrast agent. More volume (18–27 ml) than previously described (8–18 ml) [5, 6, 16, 17] was injected in the current study. Injection of a larger volume of contrast agent combined with traction enables joint distraction in most cases, according to the authors' experience. This was also the case in the current study (72/75 cases=96 %). In contrast to previous reports intra-articular injection was made in 5–10 degrees of hip flexion [5, 6, 16, 17]. According to the authors' experience, this position facilitates intra-articular injection of large volumes of contrast agent which may be explained by the fact that the hip capsular ligaments become more lax with flexion [18]. These observations have to be further investigated.

Some patients reported considerable pain. Pain before the procedure was not assessed. This may falsify some of the reported pain levels in the subset of patients who complained about severe groin pain on the day of the MR examination. Among these individuals, two patients underwent subsequent hip arthroscopy within 1 week. In one case a dislocated labral flap caused acute symptoms, and in another case a massively hypertrophic and torn ligamentum teres required timely arthroscopic treatment. According to a meta analysis [19] on complications inherent to hip arthroscopy, transient neuropraxia of the pudendal, ischial, or femoral nerve is a rare complication which is associated with portal placement, long traction times, and compression of the perineum with the counterpost. Traction time was shorter than mean arthroscopic traction time (19 min versus mean of 51.8±24.2 min) and neither portals nor perineal abutment were needed with the used traction technique. Hence, this procedure is considered to be safe though the investigated cohort was small.

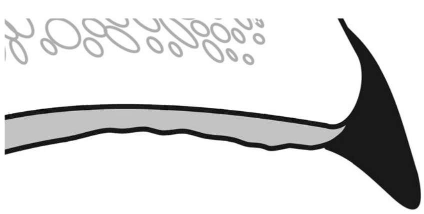

Illustration 9 Partial-thickness lesion: <50 %

According to a meta analysis by Smith and colleagues, sensitivity and specificity of conventional MR arthrography at 1.5 T in detection of labrum defects is 83 % and 57 %, respectively [2]. Diagnostic performance of traction MR arthrography (sensitivity, 93–97 %; specificity, 57–86 %) in the detection of labrum lesions was comparable with previous results of conventional MR arthrography [4, 20, 21] or noncontrast MRI [22] with sensitivity and specificity values ranging from 85–97 % and 33–100 %, respectively. Prevalence of labrum defects was high among these studies including the current report, hence interpretation of specificity should be made with caution.

Accurate characterization of signal extending into the base of the labrum was difficult in some cases between radiologists and between each radiologist and the arthroscopic gradings. A finding which may be explained by the fact that intersubstance tears may present as focal areas of intermediate signal on T1-weighted images [23]. Furthermore, focal signal alterations or fibrillation were occasionally mistaken for intrasubstance tears (Table 4). One should be aware of these variants when assessing MR arthrograms of the hip.

In the literature, diagnostic performance of MR imaging varies substantially in detection of acetabular cartilage lesions [4, 5, 17, 22, 24, 25].

Predominant pattern of acetabular cartilage lesions were delamination tears in the current study (Table 4; Figs. 3 and 4). Diagnostic studies on cartilage delamination are sparse [5, 26]. Intra-articular injection of contrast agent improved diagnostic performance compared to conventional MRI of the hip in a recent prospective study in the assessment of partial-thickness acetabular cartilage lesions for all surfaces combined with a sensitivity and specificity of 71–92 % and 25–100 %, respectively [4]. In contrast to that, Mintz and coworkers reported a sensitivity, specificity of 91–93 %, 75–85 %, and 86–93 %, 72–88 %, for two readers, respectively, in the evaluation of acetabular femoral cartilage lesions in a cohort of 92 patients on conventional high-resolution MR

Table 3 Diagnostic performance of traction MR arthrography of the hip in detection of chondral and labral lesions

Performance Value	Labrum		Acetabular Cartilage		Femoral Cartilage	
	R1	*R2*	*R1*	*R2*	*R1*	*R2*
True positive (no. of hips)	63	66	46	44	18	17
True negative (no. of hips)	6	4	22	18	51	49
False positive (no. of hips)	1	3	1	5	3	5
False negative (no. of hips)	5	2	6	8	3	4
Sensitivity (%)	93 (84–98)	97 (90–100)	88 (77–96)	85 (72–93)	86 (64–97)	81 (58–95)
Specificity (%)	86 (42–100)	57 (18–90)	96 (78–100)	78 (56–93)	94 (85–99)	91 (80–97)
PPV (%)	98 (92–100)	96 (88–99)	98 (89–100)	90 (78–97)	86 (64–97)	77 (55–92)
NPV (%)	55 (23–83)	67 (22–96)	79 (59–92)	69 (48–86)	94 (85–99)	92 (82–98)
Accuracy (%)	92 (83–97)	93 (85–98)	91 (82–96)	83 (72–90)	92 (83–97)	88 (78–94)

Note: *PPV* = positive predictive value, *NPV* = negative predictive value, *R1/R2* = reader 1/reader 2, numbers in parentheses are 95 % CI

Table 4 MR gradings versus arthroscopic gradings

Acetabular Labrum (Traction MR Arthrography)	Acetabular Labrum (Hip Arthroscopy)						
	Intact	Labral-chondral separation	Partial tear	Complete tear	Intrasubstance tear	Complex tear	Total
	R1/R2	*R1/R2*	*R1/R2*	*R1/R2*	*R1/R2*	*R1/R2*	*R1/R2*
Intact	6/4	2/0	2/1	0/0	0/1	1/0	11/6
Labral-chondral separation	0/0	9/6	4/3	0/0	0/0	0/0	13/9
Partial tear	1/2	5/9	24/26	0/0	0/0	1/0	31/37
Complete tear	0/0	0/0	1/0	0/0	0/0	0/0	1/0
Intrasubstance tear	0/0	0/0	0/0	0/0	2/1	1/1	3/2
Complex tear	0/1	0/1	7/8	0/0	0/0	9/11	16/21
Total	7	16	38	0	2	12	75
Acetabular Cartilage (Traction MR Arthrography)	Acetabular Cartilage (Hip Arthroscopy)						
	Intact	Bubble	Delamination tear	Defect	<50 % thickness	>50 % thickness	Total
	R1/R2	*R1/R2*	*R1/R2*	*R1/R2*	*R1/R2*	*R1/R2*	*R1/R2*
Intact	22/18	2/2	1/2	1/0	1/1	1/3	28/26
Bubble	0/0	1/1	0/3	1/0	0/0	0/0	2/4
Delamination tear	1/5	0/0	30/24	1/2	0/0	2/0	34/31
Defect	0/0	0/0	1/3	8/9	0/0	1/2	10/14
<50 % thickness	0/0	0/0	0/0	0/0	0/0	1/0	1/0
>50 % thickness	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Total	23	3	32	11	1	5	75
Femoral Cartilage (Traction MR Arthrography)	Femoral Cartilage (Hip Arthroscopy)						
	Intact	Bubble	Delamination tear	Defect	<50 % thickness	>50 % thickness	Total
	R1/R2	*R1/R2*	*R1/R2*	*R1/R2*	*R1/R2*	*R1/R2*	*R1/R2*
Intact	51/49	0/0	0/0	0/0	1/1	2/3	54/53
Bubble	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Delamination tear	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Defect	0/0	0/0	0/0	3/3	0/0	0/0	3/3
<50 % thickness	2/4	0/0	0/0	1/0	2/2	1/0	6/6
>50 % thickness	1/1	0/0	0/0	2/3	0/0	9/9	12/13
Total	54	0	0	6	3	12	75

Note: *R1/R2* = reader 1/reader 2

images [22]. The use of an iterative decomposition of water and fat with echo asymmetry and least squares estimation (IDEAL)-spoiled gradient-recalled echo sequence yielding the advantage of thin contiguous imaging did not improve the combined diagnostic performance of MR arthrography with a sensitivity and specificity of 74 % and 78 %, respectively, in detection of femoroacetabular cartilage lesions compared to conventional sequences [17].

According to previous investigations a subchondral line of high signal intensity is a highly specific, but rare finding on T1- and intermediate-weighted MR arthrograms [5, 26]. Alternatively, hypointense lines within the cartilage on coronal T1- and intermediate-weighted images had a sensitivity and specificity of 35–74 % and 90–95 %, respectively, in the assessment of cartilage delamination [5]. It was hypothesized that femoroacetabular coaptation prevents contrast agent from undermining delaminated cartilage areas [5, 26, 27]. Hence, Pfirrmann and colleagues [5] proposed the application of axial leg traction. Unlike conventional MR arthrography, application of leg traction achieved a sufficient femoroacetabular interface in most patients (Figs. 3, 4 and 5). In the current study, acetabular cartilage lesions were detected with a sensitivity of 85–88 % and a specificity of 78–96 % for both readers on traction MR arthrograms. Traction enabled visualization of subchondral contrast accumulation corresponding to cartilage delamination in most cases (Figs. 3 and 4), a finding which was highly specific for reader 1, whereas the less experienced reader 2 misdiagnosed curvilinear lines within acetabular cartilage as delamination tears in some cases. These findings most likely represent truncation artefacts [28] and emphasize the need for visualization in multiple planes to avoid such pitfalls.

Sensitivity and specificity values of MR arthrography range from 40–83 % and 46–91 %, respectively, in detection of femoral cartilage layers [4, 24, 25]. Femoral cartilage lesions were detected with a sensitivity and specificity of 81–86 % and 91–94 %, respectively, for both readers on traction MR arthrograms. These results are comparable with the findings of Mintz and colleagues [22].

There are several limitations of this study inherent to the retrospective study design. The arthroscopists were aware of the initial radiologic report which could have led to a potential bias. Although the presented results are encouraging, direct comparison between conventional MR arthrography and traction MR arthrography is needed to evaluate whether the application of axial leg traction improves detection of chondral and labral lesions. This was not possible since the used protocol only included multiplanar imaging for traction imaging.

In conclusion traction MR arthrography safely achieved separation of articular cartilage layers and enabled accurate detection and grading of labral and chondral lesions in this study.

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