Eur Radiol (2015) 25:2184–2193
DOI 10.1007/s00330-015-3596-4

MUSCULOSKELETAL

Unicompartmental knee arthroplasty MRI: impact of slice-encoding for metal artefact correction MRI on image quality, findings and therapy decision

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Received: 18 June 2014 / Revised: 5 January 2015 / Accepted: 12 January 2015 / Published online: 28 January 2015

Abstract

Objectives To evaluate the impact of slice-encoding for metal artefact correction (SEMAC) on image quality, findings, and therapy decision in patients with unicompartmental knee arthroplasty (UKA).

Methods Forty-five painful UKAs were examined at 1.5T-MRI (STIR, proton-density(PD)-weighted sequence, each with SEMAC and high-bandwidth). Artefact size, image quality, anatomic depiction, and clinically relevant findings were compared between SEMAC and high-bandwidth (2 readers). In 30 patients, therapy decision was retrospectively assessed by two orthopaedic surgeons without MRI, with high-bandwidth-MRI, and with SEMAC-MRI.

Results SEMAC reduced mean artefact size for STIR (11.8 cm^2 vs. 37.7 cm^2) and PD (16.8 cm^2 vs. 18.9 cm^2), $p<0.0005$ for both comparisons. SEMAC showed more blurring than high-bandwidth, $p<0.0005$. STIR-SEMAC revealed more bone marrow oedema (29 vs. 18 patients, $p=0.001$, 30 vs. 13 patients, $p<0.0005$, for reader 1 and 2 respectively). PD-SEMAC was worse in detecting meniscal lesions (6 missed, $p=0.031$, 9 missed, $p=0.004$, by reader 1 and 2 respectively) than PD-high-bandwidth. Revision-surgery was chosen in 12 and 11 patients without MRI (surgeon 1 and 2), with high-bandwidth-MRI in 15 and 14 patients, and with SEMAC-MRI in 19 and 14 patients.

Conclusions STIR-SEMAC was useful in detecting bone marrow oedema and influenced the orthopaedic surgeons' decisions towards surgery, while PD-SEMAC showed no clinical benefit.

Key Points

- *Slice-encoding for metal artefact correction (SEMAC) MRI reduces metal-induced artefact size.*
- *STIR SEMAC detects more bone marrow oedema in painful unicompartmental knee arthroplasty.*
- *STIR SEMAC can help the orthopaedic surgeon with decision making.*
- *PD SEMAC suffers from blurring of images, potentially masking relevant meniscal lesions.*
- *PD SEMAC does not improve cartilage lesion detection in the non-operated compartments.*

Keywords MRI · Knee replacement arthroplasty · Artefacts · Decision making · SEMAC

Abbreviations

SEMAC	Slice-encoding for metal artefact correction
hiBW	High bandwidth

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Introduction

The prevalence of symptomatic knee osteoarthritis has more than doubled from 1983 to 2004 [1]. The lifetime risk of developing symptomatic knee osteoarthritis was reported to be around 45 % by a recent longitudinal study [2], with two major risk factors being aging and obesity. Unicompartmental (UKA) or total knee arthroplasty (TKA) are possible therapy options for osteoarthritis [3]. UKA has a higher revision rate compared to TKA [4]. The most common reason for revision surgery of UKA is aseptic loosening (30 %) and the second most common reason is unexplained pain (23 %) [5]. While standard radiographs and computed tomography are routinely used to assess painful UKA and TKA, recently a potential role for magnetic resonance imaging (MRI) with advanced metal-artefact reduction has been reported for evaluating patients with unexplained pain after TKA [6].

Only few pilot studies with 4 to 10 patients have investigated the role of MRI after unicompartmental knee arthroplasty so far [7–9]. In the last years, slice-encoding for metal artefact correction (SEMAC) and other advanced techniques for metal artefact reduction at MRI have been implemented for clinical use in patients with total knee or total hip arthroplasty [6, 10–12]. The strength of MRI in evaluation of the periarticular soft tissue of the knee (e.g. meniscus and ligaments) combined with dedicated metal artefact reduction sequences may be very useful in the work-up of patients with painful UKA. To our knowledge no study has yet evaluated MRI of unicompartmental knee arthroplasty with SEMAC.

The purpose of our study was to compare the SEMAC sequences with optimized metal artefact reduction sequences with high bandwidth (hiBW sequences) in patients with UKA and to evaluate the impact of SEMAC on therapeutic decision making.

Materials and methods

Patients

The study was submitted to the local ethical committee and a waiver of specific formal approval was issued. Informed consent was obtained from all patients. From July 2011 to May 2013 45 consecutive patients (mean age 66.9 years, range 48-92 years) referred to our institution for evaluation of unicompartmental knee arthroplasty (21 right knees, 24 left knees; mean time since surgery 46.7±38.2 months, range 4-141 months; missing data on surgery time points from 9 patients) with MRI were included. There were 27 male patients (mean age 65.8 years, range 48-92 years) and 18 female patients (mean age 68.6 years, range 55-87 years).

Table 1 MR imaging acquisition parameters

Parameter	STIR hiBW	STIR SEMAC	PD hiBW	PD SEMAC
Orientation	Coronal	Coronal	Sagittal	Sagittal
TR/TE	6000/35 ms	6000/35 ms	5010/14 ms	5010/15 ms
Flip angle	150°	150°	135°	135°
Section thickness	4 mm	4 mm	4 mm	4 mm
Matrix	272×384	269×384	297×488	291×448
Field-of-view	20 cm	20 cm	18 cm	18 cm
Signal acquired	1	1	1	1
Excitation bandwidth	1.3 kHz	1.8 kHz	2 kHz	1.8 kHz
Readout bandwidth	620 Hz/pixel	620 Hz/pixel	485 Hz/pixel	531 Hz/pixel
Echo spacing	8.66 ms	6.98 ms	7.18 ms	7.56 ms
Echo train length	8	21	7	25
Inversion time	145 ms	145 ms	-	-
Slices	23	23	23	23
Phase-encoding	Right-to-left	Right-to-left	Anterior-to-posterior	Anterior-to-posterior
Parallel imaging (factor)	-	GRAPPA (2x)	-	GRAPPA (3x)
Slice-encoding steps	-	8	-	12
Acquisition time	3 min 32 sec	5 min 44 sec	3 min 42 sec	5 min 7 sec

Note – STIR = short-tau inversion recovery, hiBW = high bandwidth, SEMAC = slice-encoding for metal artefact correction, PD = proton-density, TR = repetition time, TE = echo time, GRAPPA = generalized autocalibrating partial parallel acquisition

MRI

All patients were examined on 1.5T MRI scanners (Magnetom Avanto and Espree, Siemens Healthcare, Erlangen, Germany) with a dedicated knee coil (8 Channel (receive only) High Resolution Knee Array, Invivo Corporation, Pewaukee, WI, USA). A coronal short-tau inversion recovery (STIR) sequence with SEMAC (STIR SEMAC), a coronal STIR sequence optimized for metal artefacts with high bandwidth (STIR hiBW), a sagittal proton-density (PD)-weighted sequence with SEMAC (PD SEMAC), and a sagittal PD-weighted sequence optimized with high bandwidth (PD hiBW) were acquired (Table 1). View-angle tilting (VAT) was part of our SEMAC sequences. In addition, a transverse STIR sequence with an optimized inversion pulse and a coronal T1-weighted sequence optimized with high bandwidth were acquired within the routine MRI protocol, but for this study these two sequences were only used for the therapeutic decision making analysis.

Quantitative analysis

The metal induced artefact size between the two coronal and two sagittal sequences (SEMAC sequences vs. hiBW sequences) were compared. Metal artefact size area was measured on one plane per sequence by one reader (C.A.A.). On coronal images the plane through the centre of the intercondylar eminence was selected for the measurement. On the sagittal images the plane in the middle of the unicompartmental prosthesis was selected.

Qualitative analysis

Two readers (C.A.A. and F.D.G. with 1 and 13 years of experience after board certification) independently assessed first STIR images from all patients (hiBW and subsequently SEMAC images on one day) and all PD images (hiBW and subsequently SEMAC images on another day). Each sequence was assessed for image quality regarding distortion, blurring, and noise on a 1-5 scale (1 = no artefacts, 2 = minor artefacts, 3 = moderate artefacts, still diagnostic quality, 4 = substantial artefacts, moderate impairment of diagnostic quality, 5 = severe artefacts, non-diagnostic quality). The depiction of anatomic structures was rated on a 1-5 scale (1 = good depiction, 2 = fully visible, blurring borders, 3 = fully visible, substantial blurring of borders, 4 = only partially visible or partially obscured by artefact, 5 = not visible) [6]. The structures assessed on coronal STIR images were: collateral ligament on the side of the unicompartmental prosthesis, pes anserine, cartilage in the femorotibial compartment without prosthesis, anterior and posterior meniscal root, and intercondylar eminence. The structures for sagittal PD images were: anterior crutiate ligament, posterior crutiate ligament, anterior and posterior meniscal root, cartilage in the femorotibial compartment without prosthesis, cartilage in the patellofemoral compartment,

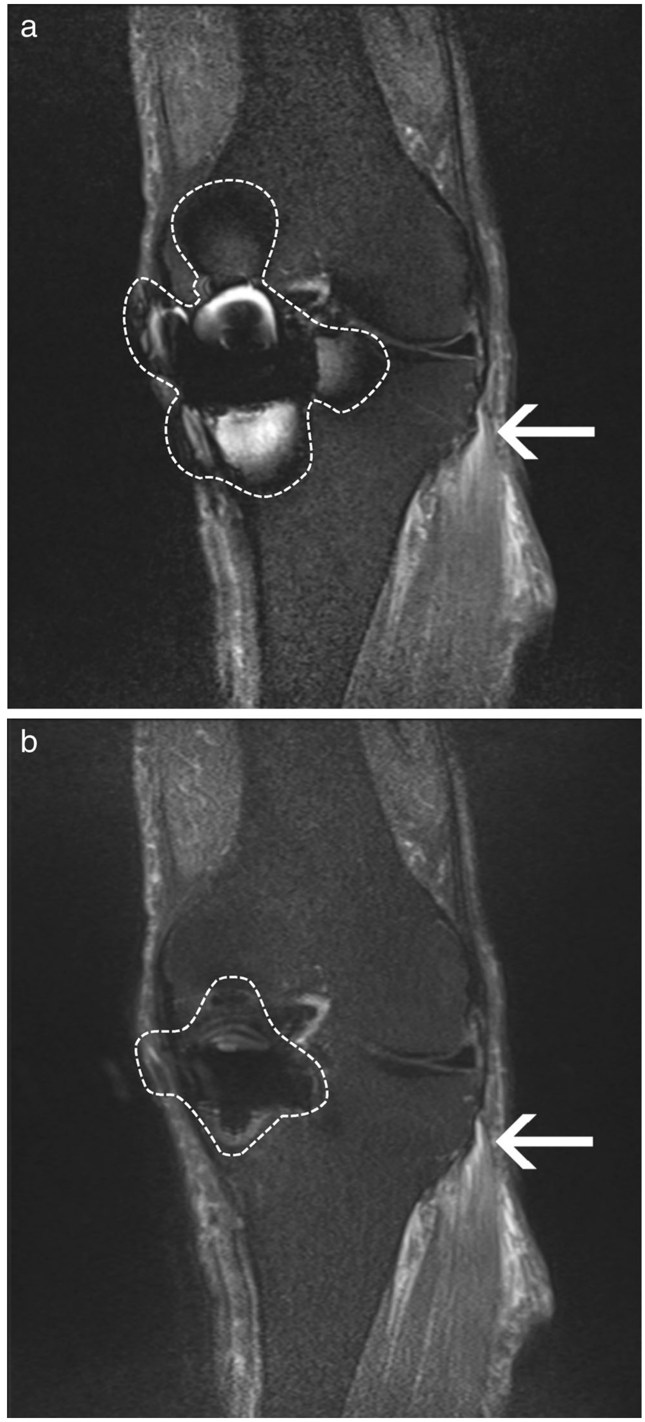

Fig. 1 92-year-old man with medial unicompartmental knee arthroplasty and left sided knee pain. (**a**) Optimized high bandwidth STIR standard sequence. (**b**) STIR sequence with slice-encoding for metal artefact correction (SEMAC). Artefact size (outlined area) is markedly smaller in the STIR SEMAC sequence (**b**) compared to the optimized high bandwidth STIR sequence (**a**). There is pronounced muscular oedema (arrow) at the origin of the tibialis anterior muscle and extensor digitorum longus muscle, explaining the patient's knee pain

Table 2 Image quality analysis

	Reader 1			Reader 2		
	hiBW	SEMAC	*P* Value	hiBW	SEMAC	*P* Value
Coronal STIR						
Distortion	3.91±0.51	2.40±0.61	<.0005	3.98±0.26	2.93±0.58	<.0005
Blurring	1.89±0.57	2.29±0.51	<.0005	1.76±0.53	2.07±0.33	<.0005
Noise	2.84±0.42	2.09±0.29	<.0005	2.93±0.25	2.09±0.29	<.0005
Sagittal PD						
Distortion	3.07±0.39	2.52±0.55	<.0005	3.00±0.43	2.84±0.61	.035
Blurring	1.96±0.56	2.75±0.53	<.0005	2.02±0.26	3.00±0.22	<.0005
Noise	2.02±0.40	2.18±0.39	.035	2.2±0.41	2.23±0.42	.739

Note – Two readers assessed image quality (distortion, blurring, and noise) in short-tau inversion recovery (STIR) and proton-density (PD)-weighted imaging, each with optimized high bandwidth (hiBW) and slice-encoding for metal artefact correction (SEMAC). A five-point scale (1 = no artefacts, 5 = severe artefacts, non-diagnostic image) was used. Data are mean±standard deviation.

and Hoffa's fat pad. Clinically relevant findings were noted and categorized into 4 groups (meniscus, ligaments, bone marrow oedema, and cartilage). Cartilage lesions were further classified by location (femur vs. tibia for the femorotibial compartment; patella vs. trochlea for the patellofemoral compartment) and severity (superficial <50 % of normal cartilage thickness or deep ≥50 %).

Clinical decision making analysis

To evaluate the impact of the SEMAC sequences on clinical decision making, two specialized orthopaedic knee surgeons (S.F.F. and S.B. with 8 and 4 years of experience after board certification) retrospectively evaluated all cases from our internal referrers, where detailed clinical charts (including notes on physical examination) and standard radiographs were available. Both orthopaedic surgeons were blinded to the therapeutic decision of the other surgeon. Both orthopaedic surgeons made a therapeutic decision (conservative therapy vs. revision surgery) based solely on the clinical charts and the radiographs (first decision). Then the MRI of the knee, comprising a transverse STIR, a coronal T1-weighted, a coronal STIR hiBW, and sagittal PD hiBW

Table 3 Depiction of anatomic details

	Reader 1			Reader 2		
	hiBW	SEMAC	*P* Value	hiBW	SEMAC	*P* Value
Coronal STIR						
Collateral ligament	3.89±0.57	3.11±0.78	<.0005	4.00±0.56	3.09±0.70	<.0005
Pes anserinus	3.82±0.68	2.98±0.62	<.0005	3.73±0.65	2.89±0.61	<.0005
Cartilage near intercondylar eminence	3.13±1.01	2.69±0.51	.003	3.29±0.90	2.69±0.56	<.0005
Anterior meniscal root	2.96±1.07	2.40±0.62	.001	2.47±0.94	2.47±0.59	.987
Posterior meniscal root	3.42±1.01	2.73±0.50	<.0005	3.09±0.73	2.84±0.37	.034
Intercondylar eminence	4.18±0.44	2.98±0.45	<.0005	3.93±0.33	2.78±0.52	<.0005
Sagittal PD						
ACL	2.84±0.90	3.23±0.57	.006	3.33±0.71	3.50±0.51	.083
PCL	3.62±0.78	3.34±0.71	.037	3.76±0.53	3.61±0.49	.083
Cartilage	2.02±0.62	2.55±0.55	<.0005	2.18±0.44	2.84±0.37	<.0005
Anterior Meniscal root	1.71±0.66	2.55±0.59	<.0005	2.16±0.48	2.86±0.51	<.0005
Posterior Meniscal root	2.04±0.56	2.91±0.47	<.0005	2.24±0.53	2.95±0.37	<.0005
Hoffa's fat pad	2.47±1.10	2.64±0.75	.144	3.07±0.65	3.20±0.46	.096

Note – Anatomic depiction was assessed on a five-point scale (1 = good depiction, 5 = not visible). Data are mean±standard deviation. hiBW = high bandwidth, SEMAC = slice-encoding for metal artefact correction, STIR = short-tau inversion recovery, PD = proton-density, ACL = anterior cruciate ligament, PCL = posterior cruciate ligament.

sequence were presented by a radiologist (C.A.A.). The orthopaedic surgeons again made a therapeutic decision (second decision). Finally, the same MRI examination was shown to the orthopaedic surgeons, but this time the coronal STIR SEMAC and sagittal PD SEMAC sequences were shown instead of the coronal STIR hiBW and sagittal PD hiBW sequences. Again a therapeutic decision was given by the orthopaedic surgeons (third decision). If therapy decision changed between second and third decision from conservative to surgery, the imaging findings on the SEMAC images that led to the change in decision were noted.

Statistics

SPSS was used for statistical analysis (IBM SPSS Version 21; SPSS, Chicago, IL). Artefact size, image quality and anatomic depiction were analyzed using a Wilcoxon signed rank test. Inter-reader agreement for depiction of anatomic structures was assessed using intraclass correlation coefficients (ICC). Differences in clinically relevant findings were analyzed using the McNemar test. The Cochran's Q Test was used to evaluate for changes in therapeutic decision. A p-value<0.05 was considered indicating a statistically significant difference.

Results

Quantitative analysis

Mean artefact size for STIR SEMAC (11.8±7.1 cm^2) was significantly smaller than for STIR hiBW (37.7±14.8 cm^2), with $p<0.0005$ (Fig. 1). Mean artefact size for PD SEMAC (16.8±5.0 cm^2) was significantly smaller than for PD hiBW (18.9±5.4 cm^2), with $p<0.0005$.

Qualitative analysis

For STIR SEMAC distortion and noise were significantly lower compared with STIR hiBW, with $p<0.0005$ for all comparisons and both readers (Table 2). STIR SEMAC showed more blurring than STIR hiBW ($p<0.0005$ for both readers, Table 2). PD SEMAC showed less distortion ($p<0.0005$ and $P=.035$ for reader 1 and 2, respectively, Table 2) but more blurring than PD hiBW ($p<0.0005$ for both readers) PD SEMAC was found to have more noise than PD hiBW, with a statistically significant difference only for reader 1 (Table 2).

STIR SEMAC was superior in depiction of all anatomic structures compared to STIR hiBW ($p\leq0.034$), except for the anterior meniscal root for reader 2 ($p=0.987$, Table 3). PD SEMAC was only better in depiction of the posterior crutiate ligament, but this was statistically significant only for reader 1 ($p=0.037$), and not for reader 2 ($p=0.083$) (Table 3). PD hiBW showed better depiction of cartilage in the non-

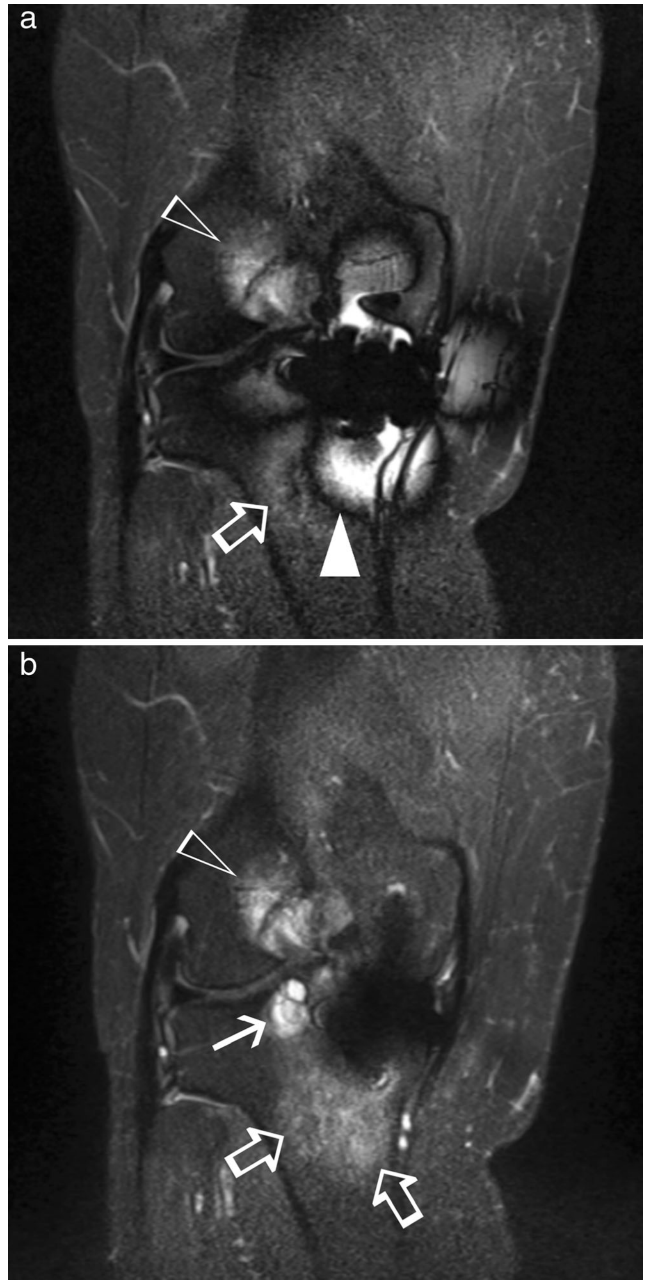

Fig. 2 55-year-old woman with a medial unicompartmental knee arthroplasty and intermittent right sided knee pain. (**a**) Optimized high bandwidth STIR sequence. (**b**) STIR sequence with slice-encoding for metal artefact correction (SEMAC). On the SEMAC image (**b**) large bone marrow oedema in the tibial metaphysis is seen (open arrows). On the high bandwidth STIR image (**a**) the bone marrow oedema (open arrow) is partially obscured by artefact (arrowhead). The bone marrow oedema in the central aspect of the lateral femur condyle (white open arrowhead) is visible in both images (**a**) and (**b**). The intraosseous ganglion cyst (arrow) near the intercondylar eminence is nicely depicted on the STIR SEMAC image (**b**), but not visible on high bandwidth STIR (**a**)

operated compartment and both meniscal roots ($p<0.0005$ for all comparison for both readers, Table 3). For the depiction of the anterior crutiate ligament PD hiBW was better, but only with a statistically significant difference for reader 1 ($p=0.006$, Table 3). For the depiction of Hoffa's fat pad no statistically significant difference was found between the two PD sequences. Inter-reader agreement for depiction of anatomic structures was fair to moderate: Mean ICC for depiction of the crutiate ligaments was 0.522 (hiBW) and 0.546 (SEMAC); for meniscal roots 0.426 and 0.259; for cartilage 0.389 and 0.320; for periarticular soft tissues (collateral ligament, pes anserine) 0.739 and 0.497, for central structures (intercondylar eminence and Hoffa's fat pad) 0.448 and 0.400.

Clinically relevant findings

Both readers found significantly more areas of bone marrow oedema with STIR SEMAC compared to STIR hiBW (Fig. 2). With STIR SEMAC reader 1 found 29 patients (30 for reader 2) with bone marrow oedema, whereas with STIR hiBW only 18 patients (13 for reader 2) with bone marrow oedema were identified (reader 1 $p=0.001$, reader 2 $p<0.0005$, Table 4). PD SEMAC was statistically significantly worse than PD hiBW in detecting meniscal lesions for both readers (Fig. 3). With PD SEMAC reader 1 missed 6 patients ($p=0.031$) and reader 2 missed 9 patients ($p=0.004$) with meniscal lesions (Table 4).

Table 4 Number of clinically relevant findings

	Reader 1			Reader 2		
	hiBW	SEMAC	*P* Value	hiBW	SEMAC	*P* Value
Coronal STIR						
Meniscus	10	9	1	5	0	1
Bone marrow edema	18	29	.001	13	30	<.0005
Ligaments	5	14	.004	0	0	N/A
Sagittal PD						
Meniscus	29	23	.031	14	5	.004
Ligaments	26	23	.25	11	11	1

Note – Clinically relevant findings were categorized into the following groups: Meniscal pathology, bone marrow oedema, ligamentous pathology, and cartilage pathology. Results for cartilage are shown in Tables 5 and 6. Bone marrow oedema was not assessed on proton-density (PD)-weighted images. Highlighted in bold are statistically significant findings. hiBW = high bandwidth, SEMAC = slice-encoding for metal artefact correction, STIR = short-tau inversion recovery, PD = proton-density, N/A = not applicable.

For lesions of the ligaments, no sequence showed a clear advantage (Table 4).

Depiction of cartilage lesions in the non-operated femorotibial compartment showed no statistically significant

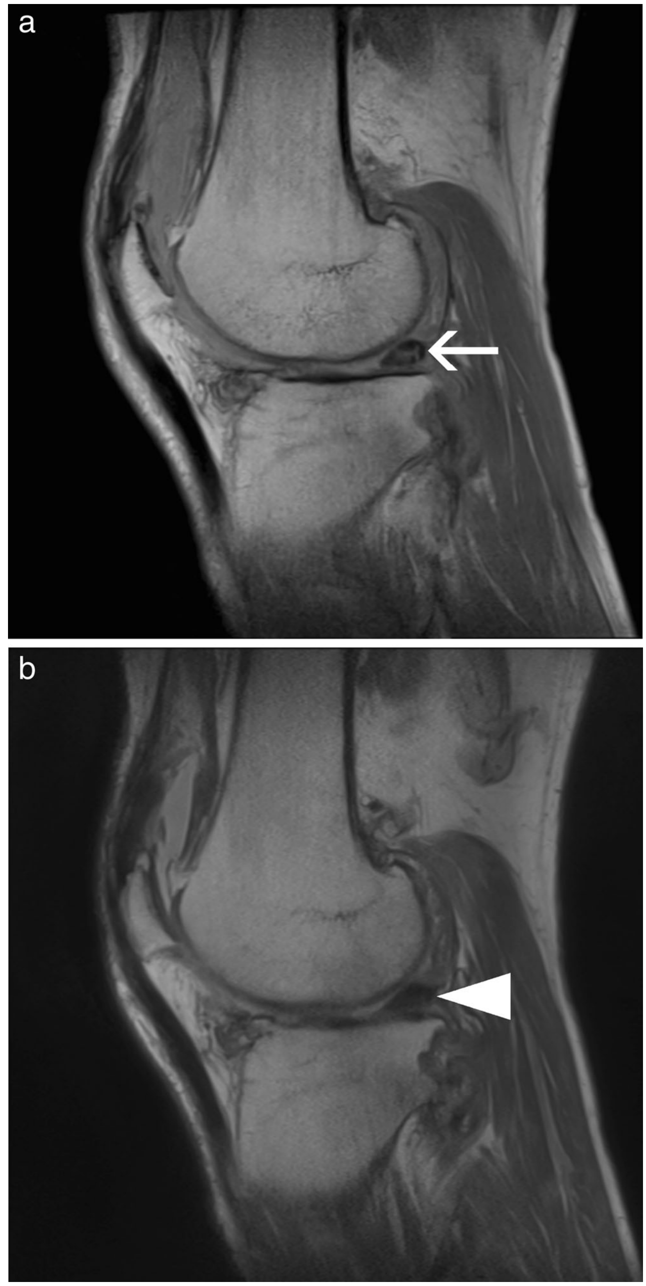

Fig. 3 71-year-old man with medial unicompartmental knee arthroplasty and progressive knee pain. Images show lateral compartment. (**a**) Optimized high bandwidth sagittal PD-weighted sequence. (**b**) PD-weighted sequence with slice-encoding for metal artefact correction (SEMAC). Left image shows a complex meniscal tear in the posterior meniscal horn (arrow, **a**), which is not seen on the PD SEMAC image (arrowhead, **b**), because of increased blurring

Table 5 Femorotibial cartilage lesions

	Reader 1			Reader 2		
	hiBW	SEMAC	*P* Value	hiBW	SEMAC	*P* Value
Coronal STIR						
Patients with any cartilage damage	15	18	.375	5	5	1
Femoral (superficial/deep)	0/9	1/7		0/4	0/4	
Tibial (superficial/deep)	1/11	3/12		0/5	0/5	
Total lesions	21	23		9	9	
Sagittal PD						
Patients with any cartilage damage	6	6	1	11	10	1
Femoral (superficial/deep)	2/4	1/4		4/5	4/5	
Tibial (superficial/deep)	1/4	1/5		3/5	2/5	
Total lesions	11	11		17	16	

Note – No statistically significant difference was found between hiBW and SEMAC for detection of cartilage lesions in the non-operated femorotibial compartment (for coronal STIR and sagittal PD). Cartilage lesions were classified as superficial (<50 % of normal cartilage thickness) and deep (≥50 % of normal cartilage thickness). hiBW = high bandwidth, SEMAC = slice-encoding for metal artefact correction, STIR = short-tau inversion recovery, PD = proton-density

difference between hiBW and SEMAC (Table 5 and Fig. 4). In the patellofemoral compartment, more patients with cartilage lesions were detected with PD hiBW compared to PD SEMAC, but this was not statistically significantly different (Table 6).

Clinical decision making analysis

Orthopaedic surgeon 1

There was an increase in revision surgery decisions for each decision step for surgeon 1 (Fig. 5). The increase from 12 to 19 patients for whom revision surgery was advised was statistically significant (p=0.005).

Orthopaedic surgeon 2

MRI with high bandwidth changed therapy decision from conservative to revision surgery in 3 patients for surgeon 2. The SEMAC sequences led to no additional revision surgery decisions for surgeon 2 when compared to the high bandwidth sequences (Fig. 5). The overall increase in decisions in favour of revision surgery from 11 to 14 patients for surgeon 2 was just at the border of statistical significance with p=0.05.

In 22/30 patients, both orthopaedic surgeons made exactly the same therapeutic decisions in each of the three decision steps. In 6 of the 8 remaining cases, final therapy decision from surgeon 1 was revision surgery, whereas surgeon 2 preferred a conservative approach. In the other 2 discrepant cases, surgeon 2 favoured revision surgery from the beginning, whereas surgeon 1 decided on revision surgery only after MRI with SEMAC in one case, and stayed on conservative treatment in the other case.

In the 4 patients where revision surgery was advised only after SEMAC by surgeon 1, the following MRI findings were only visible with SEMAC: One patient had a bone marrow oedema in the intercondylar eminence, one patient presented with a more extensive bone marrow oedema than visible on hiBW images, one patient had a small bone marrow oedema zone around the femoral component, and one patient presented with new bone marrow oedema adjacent to the tibial component.

Discussion

Our study shows that MRI with SEMAC can be successfully used in clinical routine for the evaluation of patients with unicompartmental knee arthroplasty and may have substantial influence on the therapeutic management.

Artefact size was statistically significantly reduced for all sequences with the SEMAC technique. This effect of the SEMAC technique has been shown in other studies with patients after total knee or hip arthroplasty [6, 12]. Noise was significantly reduced for STIR SEMAC compared to STIR hiBW. For PD-weighted sequences, more noise was found

Fig. 4 86-year-old woman with medial unicompartmental knee arthroplasty and pain in the tibia proximally. (**a**) Optimized high bandwidth PD sequence. (**b**) PD sequence with slice encoding for metal artefact correction (SEMAC). Both sequences show the deep cartilage defect of the tibia (black arrow). Cartilage on the PD SEMAC image (**b**) showed more blurring compared to the cartilage on the high bandwidth PD image (**a**)

with the SEMAC technique compared to high bandwidth. However, there were only small differences in mean noise values between the two sequences and a statistically significantly difference was found only for one of the two readers. The increased blurring with SEMAC compared to high bandwidth is associated with the use of view angle tilting (VAT) in our SEMAC sequences [13]. For STIR SEMAC, the increased blurring had no relevant influence on overall image quality.

STIR SEMAC was superior compared to STIR hiBW for depiction of anatomic structures around the unicompartmental knee arthroplasty. Interestingly, although the artefact size was significantly reduced with SEMAC, PD SEMAC was inferior compared to PD hiBW in depiction for most anatomic structures. The sole exception was the posterior crutiate ligament. Aliprandi et al. performed a study in 8 patients with unicompartmental knee arthroplasty without the use of metal artefact reduction techniques such as high bandwidth or SEMAC [7]. In that study the posterior cruciate ligament was undetected in all patients. However, in our study the posterior crutiate ligament was depicted every single time on PD-weighted sequences (SEMAC and high bandwidth), mostly with a sufficient quality, depending on sequence and reader.

With PD SEMAC cartilage was affected substantially by more blurring compared to PD hiBW. In the non-operated femorotibial compartment this had no relevant influence for cartilage lesion detection, while for the patellofemoral compartment less cartilage defects were detected using PD SEMAC (though this was not statistically significantly different). We explain this with the increased blurring from the PD SEMAC sequence. Metal-induced artefacts did not reach the patellofemoral compartment, which has already been shown even without the use of dedicated metal artefact reduction sequences [7].

Heyse et al. analyzed the non-operated compartment in 10 patients with UKA with MRI [9]. In their study PD-weighted sequences (axial, coronal, and sagittal) with high bandwidth for metal artefact reduction were used. They detected meniscal lesions in 9 out of 10 patients. Interestingly, in our study several meniscal lesions which were detected with the PD hiBW were missed on PD SEMAC. We explain this with the increased blurring, due to the use of VAT. No fluid sensitive sequence, such as STIR, was used in the study of Heyse et al. [9]. Therefore bone marrow oedema was not assessed in their study. Aliprandi et al. stated that detection of subchondral bone marrow oedema in STIR sequences in the non-operated compartment should not be affected by the metal induced artefacts [7]. However, our study shows that bone marrow oedema can be missed in the central tibial head or close to the prosthesis when dedicated metal artefact reduction sequences (e.g. SEMAC) are not used.

Table 6 Patellofemoral cartilage lesions

	Reader 1			Reader 2		
	hiBW	SEMAC	*P* Value	hiBW	SEMAC	*P* Value
Patients with any cartilage damage patellofemoral	37	33	.125	37	32	.063
Retropatellar (superficial/deep)	23/12	18/7		25/13	23/6	
Trochlear (superficial/deep)	13/10	13/6		24/7	15/7	
Total lesions	58	44		69	51	

Note – Patellofemoral cartilage was assessed only on sagittal PD sequences (hiBW and SEMAC). Cartilage lesions were classified as superficial (<50 % of normal cartilage thickness) and deep (≥50 % of normal cartilage thickness). In all patients, metal-induced artefacts did not alter the patellofemoral compartment.

hiBW = high bandwidth, SEMAC = slice-encoding for metal artefact correction, STIR = short-tau inversion recovery, PD = proton-density.

According to Baker et al. 23 % of UKA revision surgeries are due to unexplained pain, as shown with data from the National Joint Registry of England and Wales in the time period from 2003 to 2010 [5]. This was before the clinical introduction of new-generation metal artefact reduction sequences for MRI like SEMAC [14]. In our study STIR SEMAC was significantly better in depicting bone marrow oedema compared to STIR hiBW, due to reduction of artefact size. Since bone marrow oedema is strongly associated with pain in knee osteoarthritis [15], it is possible that at least some of the previously unexplained pain in patients with UKA might be due to missed bone marrow oedema. Our results support this theory. In all 4 patients with therapy change only after SEMAC a new bone marrow oedema was visible on the SEMAC images that had not been detected on the hiBW images.

Our study had limitations. There was only fair to moderate inter-reader agreement for the anatomic depiction analysis. This could be explained by the used scale, as for example the distinction between blurring and substantial blurring of borders is prone to subjective impression. Also, only 30 patients were eligible for the decision making analysis. The other 15 patients were external referrals, so no clinical charts or standard radiographs were available. The hiBW and SEMAC images were not presented in randomized order to the surgeons, as we wanted to see the direct impact of the SEMAC sequences. So the only thing that could change therapy decision was new information only visible on SEMAC images. Another limitation was a missing reference standard for revision surgery decisions.

In conclusion, the STIR SEMAC sequence was useful for evaluation of patients with painful unicompartmental knee arthroplasty and influenced the orthopaedic surgeon's decision towards surgery, while no clinical benefit was present for the PD SEMAC sequence.

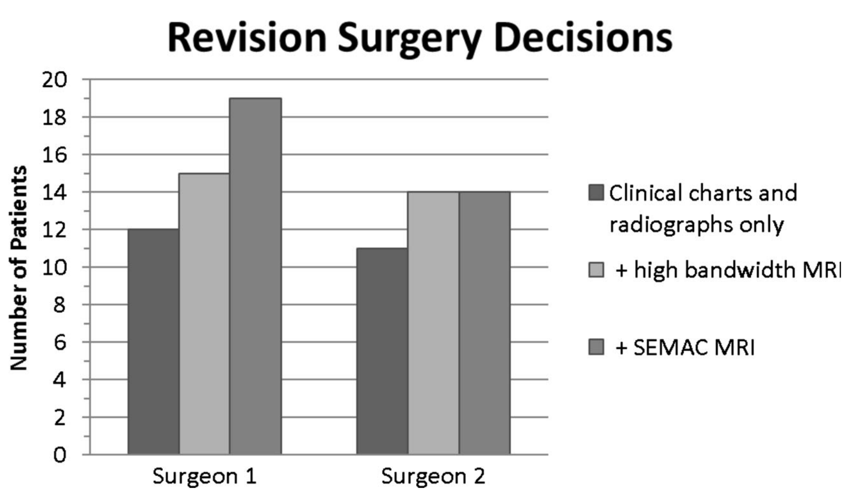

Fig. 5 For clinical decision making analysis, two orthopaedic surgeons retrospectively evaluated 30 patients in 3 decision-steps: 1. with clinical charts and standard radiographs only, 2. with additional high bandwidth MRI, and 3. with additional slice-encoding for metal artefact correction (SEMAC) sequences. At each step, they either chose conservative treatment or revision surgery. Bars show number of patients chosen for revision surgery per step and surgeon

Acknowledgements The scientific guarantor of this publication is Christoph Agten. The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article. The authors state that this work has not received any funding. No complex statistical methods were necessary for this paper. Institutional Review Board issued a waiver. Written informed consent was obtained from all patients in this study. Methodology: prospective, performed at one institution.

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