Skeletal Radiology (2019) 48:699–706
https://doi.org/10.1007/s00256-018-3084-4

SCIENTIFIC ARTICLE

Pseudoaneurysm after total knee arthroplasty: imaging findings in 7 patients

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Received: 29 May 2018 / Revised: 29 August 2018 / Accepted: 23 September 2018 / Published online: 10 October 2018

Abstract
Objective To describe the clinical presentation of arterial pseudoaneurysms following total knee arthroplasty (TKA) and their diagnostic imaging features on ultrasound and magnetic resonance angiography (MRA) in 7 patients.
Materials and methods A search of our radiology report database from 2007 to 2017 yielded 7 patients with a pseudoaneurysm diagnosed by imaging after TKA. Clinical notes and imaging were reviewed.
Results All 7 patients were male and ranged in age from 53 to 68 (mean 61) years. All patients presented with a painful swollen knee and hemarthrosis within the first month following surgery. Five patients presented after primary TKA. One patient presented after explantation for septic arthritis and another after partial synovectomy for septic arthritis without explantation. Ultrasound identified the pseudoaneurysm as a hypoechoic or hyperechoic mass with a "yin-yang" appearance of turbulent arterial flow and associated complex joint effusion. On MRA, the pseudoaneurysm was a mass next to a parent artery showing avid contrast enhancement in the arterial phase that persisted into the venous phase and washed out in the late venous phase. Six pseudoaneurysms arose from lateral geniculate arteries and 1 from a medial geniculate artery. There were no popliteal artery pseudoaneurysms. Five patients were treated endovascularly, 1 patient thrombosed without intervention, and 1 patient was treated with open surgery.
Conclusion Pseudoaneurysm is a potential source of a painful swollen knee with hemarthrosis or a drop in hematocrit after TKA and can be identified with either ultrasound or MRA.

Keywords Total knee arthroplasty · Pseudoaneurysm · Ultrasound · Magnetic resonance angiography · Hemarthrosis

Introduction

Arterial complications, including transection, thrombosis, and pseudoaneurysm, are rare after total knee arthroplasty (TKA), with a prevalence of 0.03-0.2% of all patients [1–4]. Although most arterial complications are promptly diagnosed and treated intraoperatively, a contained arterial bleed can present as a pseudoaneurysm at a later date and pose a diagnostic challenge [5]. Pseudoaneurysms around the knee can present with many different signs and symptoms, including recurrent hemarthrosis, swelling, decreased range of motion, pain, pulsatile mass, and common peroneal neuropathy [6, 7]. Although uncommon, pseudoaneurysms are serious complications that can impede postoperative rehabilitation [8].

Pseudoaneurysms after TKA can involve the popliteal artery, geniculate arteries, or the anterior tibial artery [6, 9–14]. The popliteal artery can be indirectly injured when the knee is placed in hyperextension intraoperatively, and there is an increased risk when the popliteal artery is atherosclerotic because of decreased elasticity [3, 15]. Any of the arteries are susceptible to injury owing to instrumentation; the popliteal artery can be injured and result in a pseudoaneurysm during release of the posterior capsule in knees with a flexion contracture [15], whereas either the superior lateral geniculate artery or the inferior medial geniculate artery can be injured during release of the lateral or medial structures respectively, for soft-tissue balancing [16, 17].

Small case series have described pseudoaneurysms after TKA involving the popliteal, geniculate, or anterior tibial

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arteries [6, 9–14]. Several larger retrospective studies in the orthopedic and vascular surgery literature describe up to nine patients [1, 5, 15]. However, there have been few reports of this complication in the radiology literature [15, 18–21], with only one review article demonstrating a pseudoaneurysm after TKA with magnetic resonance angiography (MRA) and ultrasound [18]. The purpose of this retrospective study is to describe the clinical presentation of arterial pseudoaneurysms following TKA and their diagnostic imaging features on ultrasound and MRA in 7 patients.

Materials and methods

This retrospective study, including waiver of informed consent, was approved by the Institutional Review Board before initiation of the study. Electronic search of our radiology department's report database from 2007 to 2017 was performed using the keywords "pseudoaneurysm," "aneurysm," and "knee" to first identify a group of potential patients. The images and reports of these patients were reviewed to isolate only those patients fitting the inclusion criteria of the study, which consisted of a pseudoaneurysm of the knee diagnosed on a radiological study following TKA of the ipsilateral knee. The images were also reviewed to confirm that the lesion in question is not a preexisting aneurysm related to atherosclerosis. Exclusion criteria were the presence of trauma that could have resulted in the pseudoaneurysm and the absence of imaging confirmation of the pseudoaneurysm.

Ultrasound was performed on either Philips iU22 (before 2016; Philips Medical Systems, Bothell, WA, USA) or GE Logiq E9 (2016 and more recently; General Electric Healthcare, Milwaukee, WI, USA) units. MRA was performed on 1.5-Tesla clinical magnets (General Electric Healthcare, Milwaukee, WI, USA) using a high-resolution contrast-enhanced time-resolved 3D technique known as time-resolved imaging of contrast kinetics (TRICKS), as per our standard clinical protocol. After acquiring a precontrast sequence used as a "mask," a bolus of intravenous contrast medium (either 0.2 mmol/kg gadodiamide [General Electric Healthcare] or 0.1 mmol/kg gadobutrol [Bayer Healthcare, Whippany, NJ, USA]) was injected and rapid three-dimensional T1-weighted gradient-echo sequences were obtained for a total of 24-26 phases within approximately 5 min. Subtraction of the "mask" from each contrast phase yielded the post-processed MRA images for interpretation. Most of the MRAs also included an axial proton density sequence of the knee before gadolinium administration. One patient had a full diagnostic MRI of the knee immediately before MRA, including axial, sagittal, and coronal proton density, axial inversion recovery, multi-acquisition variable-resonance image combination (MAVRIC) sagittal proton density, and MAVRIC sagittal inversion recovery. All imaging studies were retrospectively reviewed by a board-certified musculoskeletal radiologist with 7 years of subspecialty experience.

Results

Demographics in addition to clinical and imaging data are summarized in Table 1. Among the approximately 1.9 million patients who had a radiology examination at our institution during the 11-year period from 2007 to 2017, a search through the radiology reports using the keywords "pseudoaneurysm," "aneurysm," and "knee" yielded 483 potential patients. This was reduced to 72 patients after the reports were read and those without an aneurysm or pseudoaneurysm in the knee (for example, those whose report stated "there is no pseudoaneurysm") were excluded. This was further reduced to 13 patients once the cohort was limited to those with a history of TKA in the same knee. Finally, 7 patients remained once the images and radiology reports were reviewed and those with aneurysms of the popliteal artery typical of atherosclerotic disease were excluded. Among the 7 patients, 5 had undergone recent primary TKA, 1 had undergone explantation of the TKA and placement of an antibiotic spacer for septic arthritis 2.5 years after the initial TKA, and the last patient had undergone partial synovectomy without explantation for septic arthritis, also 2.5 years after initial TKA placement. One surgeon operated on 3 of the patients, a second surgeon operated on 2 of the patients, and two other surgeons operated on the last 2 patients, all of whom had at least 20 years of experience performing knee joint replacement surgeries, and the same general surgical approach was utilized for all the patients. All presented within 1 month of their most recent surgery. All patients were on Coumadin® for deep venous thrombosis prophylaxis, except for one, whose post-operative anticoagulation status was unclear. Maximum dimensions of the pseudoaneurysms ranged between 1.0 and 3.5 cm.

All 7 patients presented with a painful swollen knee, documented or clinically suspected hemarthrosis, and a drop in hematocrit, with 3 patients requiring transfusions. An iatrogenic pseudoaneurysm was clinically suspected in several of the patients, especially those with a significant drop in hematocrit requiring transfusions. A pulsatile mass was not present in any of the patients.

All 7 patients underwent either ultrasound or MRA; 3 patients underwent both MRA and ultrasound, 2 underwent MRA alone, 1 underwent ultrasound alone, and 1 underwent ultrasound after CT angiography. The last patient was initially evaluated using CT angiography because the patient was reluctant to have an MRI owing to claustrophobia. Ultrasound confirmed the presence of a pseudoaneurysm after CT angiography revealed a hyperdense mass in the joint that did not definitively connect to an opacified artery, suspicious for either a pseudoaneurysm or a clotted hematoma (Fig. 1).

Table 1 Clinical and demographic data of patients with a pseudoaneurysm after total knee arthroplasty

Patient age (years), gender	Previous surgery of the same knee before the most recent surgery	Medical risk factors	Time of symptom onset after surgery	Imaging showing pseudoaneurysm	Feeding artery	Pseudo-aneurysm size (cm)	Anti-coagulated?/highest INR around the time of diagnosis	Treatment
53, male	TKA	Unknown	1 week[a]	MRA	Right inferior lateral geniculate	3.4 × 3.2 × 2.3	Yes/2.0	Coil embolization
63, male	Arthroscopy	Atrial fibrillation and aortic valve replacement	4 weeks	Ultrasound followed by MRA 2 days later	Left inferior lateral geniculate	2.5 × 1.3 × 1.6	Yes/3.3	Follow-up ultrasound showed thrombosis of pseudo--aneurysm
61, male	ACL reconstruction and TKA	Hyperlipidemia	2 weeks[b]	Ultrasound followed by MRA 2 days later	Right superior lateral geniculate	1.4 × 1.0 × 0.9	Unknown	Particle embolization for synovial hyperemia
65, male	Unknown	Unknown	2 weeks	MRA	Left inferior lateral geniculate	1.7 × 1.5 × 1.0	Yes/1.5	Coil embolization
68, male	Unknown	Unknown	4 weeks	Ultrasound	Left inferior lateral geniculate	1.2 × 1.0 × 0.9	Yes/2.3	Coil embolization
53, male	Arthroscopy	Hypertension	2 weeks	MRA followed by ultrasound the next day	Left superior lateral geniculate	1.1 × 0.9 × 0.9	Yes/1.9	Coil embolization
62, male	None	Hypertension, cardiomyopathy and heart block	2-3 days	CT angiography followed by ultrasound on the same day	Right medial geniculate	2.0 × 2.0 × 1.2	Yes/1.7	Open surgery

TKA total knee arthroplasty, *ACL* anterior cruciate ligament, *MRA* magnetic resonance angiography, *CT* computed tomography, *INR* international normalized ratio

[a] Explantation of TKA and placement of an antibiotic spacer

[b] Synovectomy for treatment of septic arthritis after previous TKA

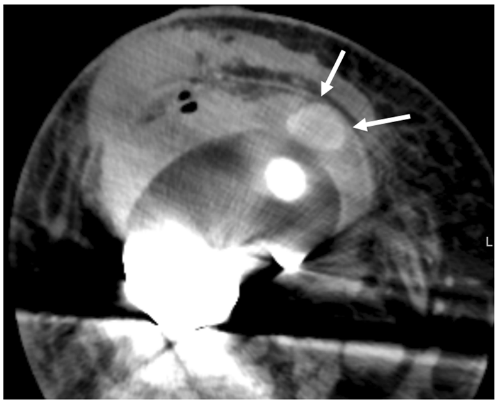

Fig. 1 A 62-year-old man with painful hemarthrosis 2–3 days after total knee arthroplasty (TKA). Axial CT image from CT angiography shows the hyperdense mass (*arrows*) indicating the pseudoaneurysm along the medial side of the knee

In all patients in whom ultrasound was performed, the pseudoaneurysm was identified as a mass with a heterogeneously thick wall and classic "yin-yang" appearance of to-and-fro turbulent arterial flow on color Doppler (Fig. 2). In 4 patients, the mass was hypoechoic and in 1 the mass was homogeneously hyperechoic, probably because of the slow, turbulent blood flow (Fig. 3). The pseudoaneurysm neck was not consistently identified and although medial versus lateral could be inferred, the parent artery could not be identified by ultrasound in any of the patients. A large complex joint effusion containing hyperechoic debris/hematoma was present in the knee in all patients. Ultrasound excluded deep vein thrombosis in all those patients in whom it was of clinical concern.

Magnetic resonance angiography diagnosed the pseudoaneurysm in all 5 patients in whom it was performed. Characteristic MRA findings of pseudoaneurysm included a circular or lobulated mass in close proximity to the parent artery demonstrating avid contrast enhancement in the arterial phase that persisted into the early venous phase and then washed out in the late venous phase (Fig. 2). In all 5 patients, the parent artery was confidently identified (inferior lateral geniculate artery in 3 patients and superior lateral geniculate artery in 2 patients) as it directly fed into the pseudoaneurysm in each case.

Four of the 5 MRAs also included an axial proton density sequence of the knee before gadolinium administration, whereas the last MRA was preceded by a full diagnostic MRI of the knee. All showed large complex joint effusions. On the axial proton density sequence, the pseudoaneurysm appeared as a hyperintense mass in 3 patients (Fig. 4), a hypointense mass in 1 patient (Fig. 5), and was invisible in 1 patient. Upon retrospective review, none of the lesions could confidently be diagnosed as a pseudoaneurysm without MRA. In 1 patient in whom pseudoaneurysm was diagnosed on MRA, an ultrasound was subsequently requested by the vascular surgeon to better depict the neck of the lesion.

A preoperative MRI of the same knee was available in 1 patient, performed 18 months before placement of the TKA, confirming that the pseudoaneurysm was not present before the surgery. In the remainder of the patients, there was no relevant history or clinical symptoms to suggest that the pseudoaneurysm had existed before surgery.

Five patients underwent digital subtraction angiography (DSA) at the time of planned endovascular treatment. The pseudoaneurysm was identified in 4 patients as an extravascular collection of contrast medium that opacified in the arterial phase and washed out during the venous phase and was treated with coil embolization (Fig. 2). In the fifth patient, the pseudoaneurysm that had been identified on both ultrasound and MRA was not seen on DSA, presumably

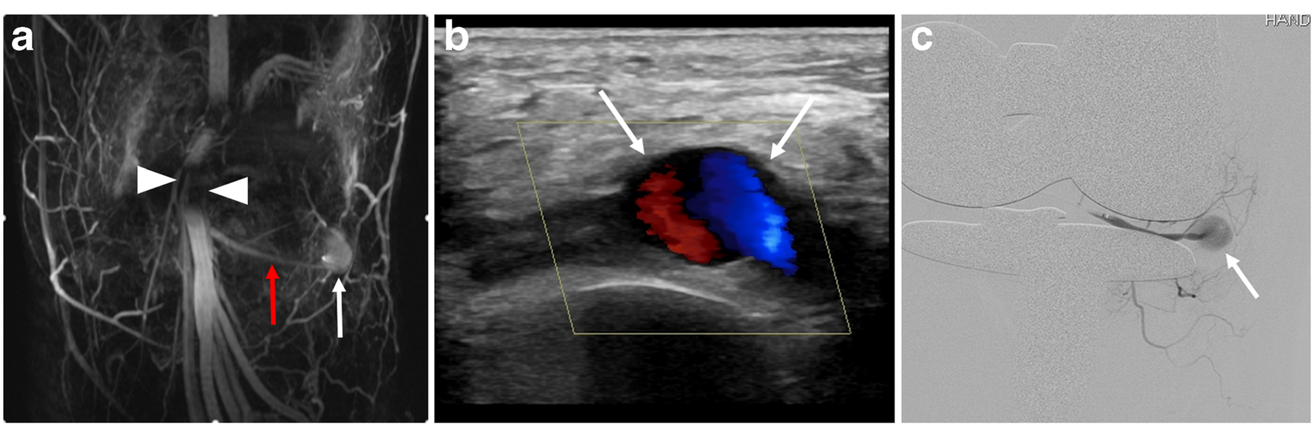

Fig. 2 A 65-year-old man with recurrent hemarthrosis 2 weeks after TKA owing to a pseudoaneurysm of the left inferior lateral geniculate artery, which was treated with coil embolization. **a** Coronal MRA image shows an enhancing mass (*white arrow*) at the level of the joint space that is contiguous with the left inferior lateral geniculate artery (*red arrow*). Apparent filling defect in the popliteal artery (*arrowheads*) is due to susceptibility artifact from the TKA. **b** Ultrasound image transverse to the knee shows the pseudoaneurysm as a fusiform mass with characteristic to-and-fro arterial blood flow (*white arrows*). **c** Selective digital subtraction angiography with a catheter in the inferior lateral geniculate artery shows contrast medium filling the pseudoaneurysm (*white arrow*)

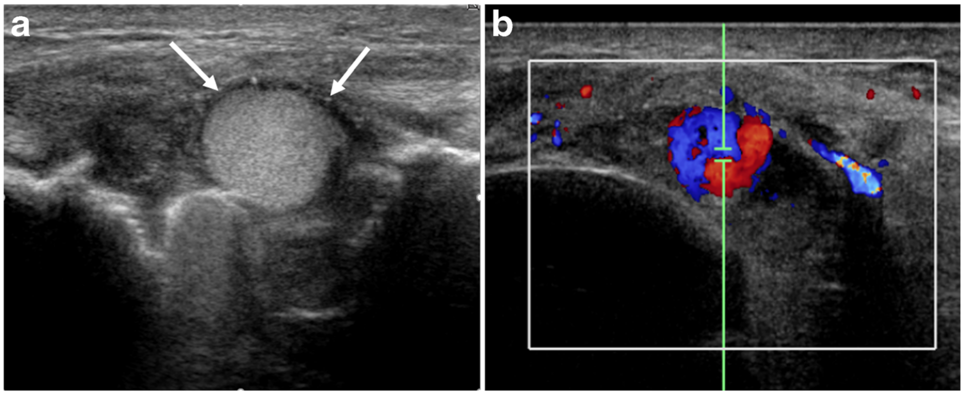

Fig. 3 A 68-year-old man presenting with swelling, pain, and hemarthrosis due to a pseudoaneurysm of the inferior lateral geniculate artery 1 month after a primary TKA. **a** Gray-scale ultrasound image coronal to the lateral side of the knee shows the pseudoaneurysm as a homogeneously hyperechoic mass along the lateral joint line (*arrows* proximal tibia). **b** Color Doppler transverse to the knee shows the classic to-and-fro pattern of arterial blood flow. This pseudoaneurysm was subsequently treated with coil embolization (not shown)

because of spontaneous thrombosis, and synovial hyperemia in the region of the superior and inferior lateral geniculate arteries was identified and treated with particle embolization. One patient underwent open surgery during which a pseudoaneurysm arising from the medial geniculate artery was oversewn with a suture. In 1 patient, the pseudoaneurysm was noted to be thrombosed on repeat ultrasound performed immediately before the planned endovascular treatment, obviating the need for further intervention.

Discussion

A painful swollen knee after TKA can have a variety of causes. Mechanical causes such as periprosthetic fracture or dislocation are usually apparent based on the clinical history and radiographs. Infection, including cellulitis, septic bursitis, and septic arthritis, result in a swollen knee but skin erythema, accompanying fever, and elevated serum inflammatory markers often point to the diagnosis. Acute deep venous thrombosis is also a potential cause of a painful swollen knee with symptoms in the back of the knee and often with involvement of the calf or the thigh depending on the extent of venous involvement. Impingement of soft tissues by the prosthetic components and hypervascular synovium are other known sources of recurrent hemarthrosis besides a pseudoaneurysm [8, 21–23].

Pseudoaneurysm is a rare though serious complication of TKA. Troutman et al. identified 8 pseudoaneurysms in the previous 39,196 TKAs at their institution [5]. In the current study, the incidence of pseudoaneurysm after TKA is

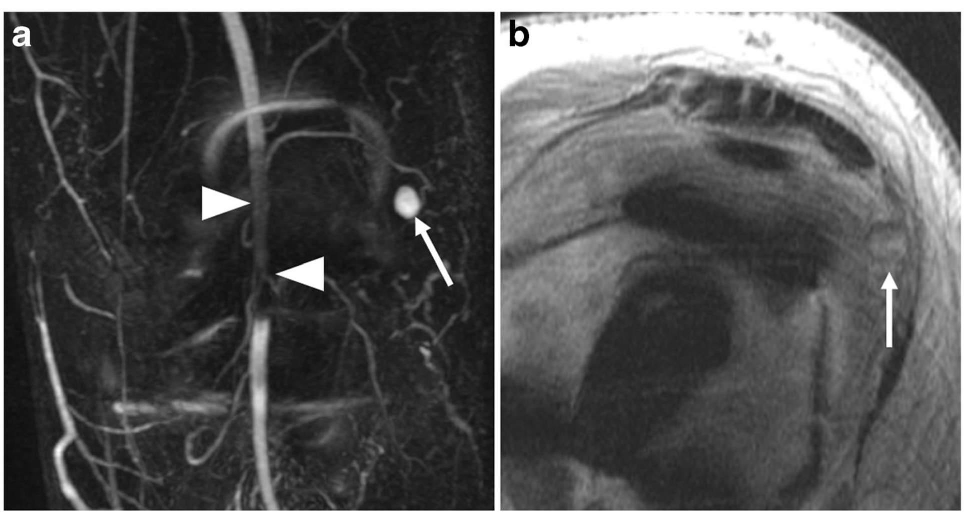

Fig. 4 A 53-year-old man with recurrent hemarthrosis due to a pseudoaneurysm of the superior lateral geniculate artery 2 weeks after primary TKA. **a** Coronal MRA shows a small enhancing mass in the superolateral aspect of the joint representing the pseudoaneurysm (*arrow*). The apparent filling defect in the popliteal artery (*arrowheads*) is due to susceptibility artifact from the TKA. **b** Axial proton density MR image before contrast medium administration shows a focal, round, hyperintense lesion representing the pseudoaneurysm (*arrow*)

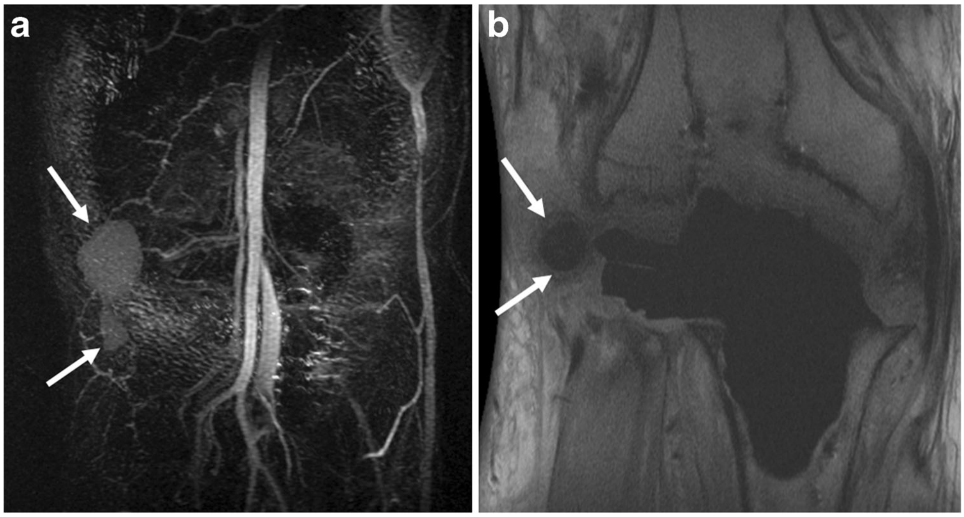

Fig. 5 A 53-year-old man with knee pain and hemarthrosis due to a pseudoaneurysm of the inferior lateral geniculate artery 1 week after explantation of a TKA and placement of an antibiotic spacer for septic arthritis. **a** Coronal MRA shows a large bilobed pseudoaneurysm (*arrows*). **b** Coronal proton density MR image obtained before the MRA shows a round hypointense mass representing the pseudoaneurysm (*arrows*)

similar, at approximately 0.02%, given an average of 4,500 TKAs performed annually at our institution (unpublished institutional data). This includes only symptomatic pseudoaneurysms diagnosed on imaging; the actual incidence of pseudoaneurysms is likely higher, as some may have been diagnosed clinically without imaging confirmation, and some small pseudoaneurysms may go undetected [8].

Characteristic imaging findings of a pseudoaneurysm were present in all 5 patients in whom ultrasound was performed. Pseudoaneurysms have been well described on ultrasound as being a single- or multi-lobed mass with variable echogenicity adjacent to the parent artery and demonstrating bidirectional color Doppler flow [24]. The bidirectional flow, which is often described as having a swirling motion or the "yin-yang sign," is characteristic, although not pathognomonic for a pseudoaneurysm, as it can occur in saccular aneurysms as well. The diagnosis is verified if the mass demonstrates a communicating channel, or neck, between it and the parent vessel [25]. Communication with the parent artery could not be detected in any of our ultrasound patients, likely because the parent artery was small and the neck was obscured by postoperative soft-tissue edema.

In general, MRI is the examination of choice for a painful TKA in the setting of unremarkable radiographs [18]. In our cohort, the MRAs were preceded by a full diagnostic MRI in 1 patient and included axial proton density sequences in the 4 others. A large complex joint effusion was seen in each, and all except one showed either a hyperintense or hypointense mass, which, in retrospect, corresponded to the pseudoaneurysm, but a pseudoaneurysm could not be confidently diagnosed before the MRA in any of the patients.

The TRICKS method is a time-resolved MRA technique in which multiple sequential sets of data can be acquired within a volume of tissue after a single contrast bolus [26–28]. TRICKS is less susceptible to abnormal hemodynamics and thus more accurate than traditional bolus-chase MRA techniques [26]. Reports of the use of time-resolved MRA for evaluating true aneurysms and pseudoaneurysms have been limited to a few case reports and pictorial reviews, but the features of pseudoaneurysms are similar to those previously described [27, 29].

In our study, MRA using TRICKS identified the pseudoaneurysm and the parent artery in all 5 patients as a mass in close proximity to the artery that rapidly enhanced in the arterial phase and washed out in the late venous phase. Aside from pseudoaneurysms, MRA is also useful for identifying hypervascular synovium as a source of hemarthrosis, although Hash et al. did not find any cases of pseudoaneurysm in their series of 18 patients [23]. The discrepancy between their results and the results of our study is that all of their patients were evaluated at least 2 months after TKA placement, whereas all of our patients presented during the first month after surgery.

Five of the 7 patients underwent conventional angiography, which verified the pseudoaneurysm in 4 patients. In 1 patient, the pseudoaneurysm identified on ultrasound and MRA was not seen on angiography performed 6 weeks later, but synovial hyperemia in the superior and inferior lateral geniculate artery distributions was identified and treated using particle embolization. The pseudoaneurysm had likely thrombosed before angiography and the patient's persistent pain and bleeding were felt to be the result of hypervascular, inflamed synovium. In another patient, repeat ultrasound immediately before angiography showed that the previously noted pseudoaneurysm had thrombosed. Thrombosis of a pseudoaneurysm around the knee after TKA without intervention has been previously described [30].

In 1 patient, CT angiography was the initial imaging modality, showing a hyperdense mass that could have been either a pseudoaneurysm or a clotted hematoma. CT angiography may play a role in patients suspected of a pseudoaneurysm after TKA, but we feel that either ultrasound or MRI/MRA is more appropriate. A precontrast phase of CT angiography is necessary to distinguish a pseudoaneurysm from a clotted hematoma as in our patient, which would increase the radiation dose. In addition, streak artifact from the metal obscures the tissues immediately around the prosthesis, potentially resulting in a false-negative result with CT angiography.

Six of the 7 pseudoaneurysms involved the superior or inferior lateral geniculate arteries and only 1 pseudoaneurysm involved the medial geniculate vessels. It is well known that the superior lateral geniculate artery is at risk for injury during lateral retinacular release and that the inferior lateral geniculate artery is at risk during both excision of the lateral meniscus and during retraction [17, 31, 32]. The inferior medial geniculate artery is at risk for injury during release of the medial structures for soft-tissue balancing at the time of TKA [16]. Although there are no specific known risk factors for injury to the superior medial geniculate artery, injury has been reported and is thought to be due to excessive knee extension and flexion during TKA placement [30, 31]. The one medial pseudoaneurysm in our study occurred in a patient who had undergone extensive medial soft-tissue release in an attempt to correct a varus deformity. Interestingly, we did not encounter any pseudoaneurysms of the popliteal artery, as has been previously described [5, 9, 14]. The popliteal artery can be injured during retractor placement, knee hyperextension, and posterior capsule release [33, 34]. We also did not observe any pseudoaneurysms involving the anterior tibial artery, which can be injured during retraction of the lateral soft tissues, especially if there is a high division of the popliteal artery [13].

We propose an imaging algorithm for the work-up of a painful swollen knee with hemarthrosis or a drop in hematocrit after TKA (Fig. 6). Ultrasound is a good initial test for targeted evaluation as it is fast, cheap, and does not require intravenous contrast medium or radiation. MRI with MRA however provides a better global assessment of the joint and should be performed if there is a need to assess for other abnormalities in addition to a pseudoaneurysm, or if ultrasound is negative, but the clinical concern for a pseudoaneurysm remains high.

The main limitation of this study is its retrospective design, which may have contributed to the underdiagnosis of pseudoaneurysms. Also, not all patients with hemarthrosis undergo imaging with ultrasound or MRA and patients may also have been diagnosed at an outside facility. However, the intent of the current study was to simply describe the clinical and imaging features of pseudoaneurysms after TKA and not to determine the precise incidence. The study is also not able to report on the diagnostic accuracy of ultrasound and MRA for pseudoaneurysms owing to the retrospective nature and the small sample size, although each modality was able to detect the pseudoaneurysm in all patients in which they were used.

Pseudoaneurysm after TKA on ultrasound and MRA is not a diagnostic dilemma and appears similar to pseudoaneurysms anywhere else, including that involving the common femoral artery in the groin as a complication of catheterization. However, this study highlights the need for awareness among both musculoskeletal and general radiologists that a pseudoaneurysm is a known source of a painful swollen knee in the clinical setting of either documented or suspected hemarthrosis after recent TKA.

In conclusion, we have shown that both ultrasound and MRA can accurately identify arterial pseudoaneurysms of the knee after TKA. Radiologists must be aware that a geniculate artery pseudoaneurysm is a potential source of a painful

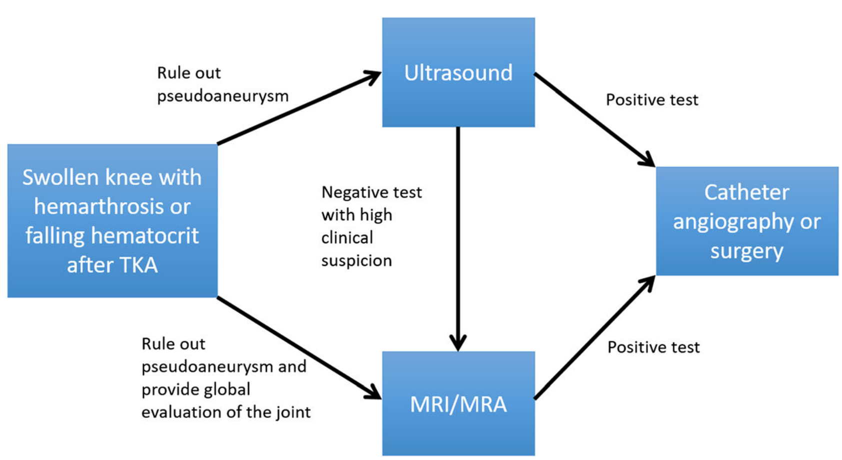

Fig. 6 Proposed algorithm for imaging evaluation of a painful swollen knee with hemarthrosis or a drop in hematocrit after TKA

swollen knee with hemarthrosis or drop in hematocrit after recent TKA, and a mass containing to-and-fro turbulent internal arterial flow on ultrasound or showing avid contrast enhancement in close proximity to a parent artery on MRA is diagnostic of this entity.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

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