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SCIENTIFIC ARTICLE

Characterization of intramuscular calf vein thrombosis on routine knee MRI

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Abstract

Objective Literature regarding intramuscular calf vein thrombosis (IMCVT) or infrapopliteal deep vein thrombosis (DVT) evaluation by magnetic resonance imaging (MRI) is limited, particularly with regard to routine unenhanced knee examinations. We attempt to correlate routine unenhanced MRI findings with ultrasound evaluations of the lower extremity deep venous system.

Materials and methods The radiology information system was searched, yielding a total of 67 patients who had undergone both routine knee MRI and duplex ultrasound examinations within 14 days. The MRI examination findings recorded were the presence and pattern of edema, segmental vein dilation, intraluminal signal on fluid-sensitive sequences, and abnormal hyperintense signal on axial T1-weighted sequences. The presence and extent of thrombus more centrally (i.e., intramuscular calf vein thrombosis with or without extension into the popliteal vein) was reassessed on ultrasound.

Results When comparing patients with positive ($n = 13$) and negative ($n = 54$) ultrasound, there were significant differences in each of these parameters: perivascular edema, intramuscular edema, focal vein dilation, and abnormal fluid-sensitive signal. In the subset of patients with popliteal extension of the intramuscular calf vein thrombosis compared with those without any deep vein thrombosis, there was a statistically significant increase in peripopliteal edema, abnormal fluid-sensitive signal, and abnormal hyperintense T1 signal.

Conclusion Imaging findings on routine unenhanced MRI have a high rate of concordance with duplex ultrasound performed through the calf in the detection of intramuscular calf vein thrombosis.

Keywords MRI · Deep vein thrombosis · Intramuscular calf vein thrombosis · Ultrasound

Introduction

Knowledge of the deep venous anatomy is imperative for the correct diagnosis and clinical management of intramuscular calf vein thrombosis (IMCVT). The intramuscular calf veins, the soleal, and the medial and lateral gastrocnemius veins are part of the deep venous system of the calf, which also includes the intergemellar vein [1]. As part of the deep venous system, these veins carry the risk of central propagation into the femoropopliteal veins and the possibility of embolization to the pulmonary vasculature [2, 3]. Early venographic studies highlighted the significance of the intramuscular calf veins, as IMCVT represented 24–34% of all cases of deep vein thrombosis (DVT) [4–7]. In a 1994 study, isolated IMCVT was present in 34% of the studied population [7]. At present, it is uncommon for patients to undergo venography, as the evaluation for deep venous thrombosis has been supplanted by duplex ultrasound examination. Ultrasound accuracy in evaluating for DVT has been repeatedly documented, with sensitivity rates as high as 94% for proximal (femoropopliteal) DVT and 64% for distal calf vein DVT. This lower sensitivity in the calf veins, compounded by protocols that frequently end evaluation at the inferior aspect of the popliteal vein, create the possibility of false-negative examinations. In cases of

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missed diagnosis by ultrasound, or of an unclear or discordant clinical history of DVT, a routine MRI of the knee may be performed to evaluate for musculoskeletal causes of symptoms. It is on these examinations that IMCVT may be incidentally detected.

The literature is limited to MRI venography evaluation of DVT and a handful of case reports of DVT on routine unenhanced or contrast-enhanced knee MRI examinations that describe muscle edema, abnormal intravascular signal, or rim-enhancing intramuscular tubular structures on contrast-enhanced MRI [8–14]. Given the relative paucity of literature regarding this topic, IMCVT may go undetected, unmanaged, and unresearched. The primary objective of this study was to correlate MRI findings with ultrasound findings to systematically characterize the MRI findings associated with IMCVT.

Materials and methods

This Health Insurance Portability and Accountability Act-compliant retrospective study was approved by our institutional review board and included studies from June 2011 to June 2017.

A search of the radiology information system for routine knee MRI was performed using M*Model Fluency Discovery (M*Model Corporation, Franklin, TN, USA). Keyword searches were performed, including "intramuscular vein thrombosis" or "calf vein thrombosis." Inclusion criteria included routine unenhanced knee MRI examinations with lower extremity duplex ultrasound performed within 14 days before or after were recorded. This helped to acquire positive cases in addition to control cases with no evidence of IMCVT or central DVT. Patients were excluded if the MRI and ultrasound examinations were not performed within this timeframe. The MRI reports and duplex ultrasound reports were recorded.

The MRI examinations consisted of routine unenhanced protocols that included axial proton density (PD)-weighted fat-suppressed (FS) sequences (repetition time [TR] range/echo time [TE] range 2,016–4,106/18–42.84 ms) and fluid-sensitive (PD- or T2-weighted) FS coronal and sagittal images (coronal 2,357–5,750/68.88–77.64 ms, and sagittal 2,093–6,211/65.83–96.21 ms). Axial T1-weighted (483–899/8.78–12.58 ms) images were obtained in some MRI examinations. Coronal T1-weighted sequences were not included in the study because the standard protocol did not extend posteriorly enough to include the calf veins. The field of view ranged in the axial plane from 130 to 190 mm, in the coronal plane from 130 to 200 mm, and in the sagittal plane from 130 to 180 mm. The ultrasound examination utilized a common protocol of grayscale, graded compression, color Doppler, and continuous wave Doppler techniques. The ultrasound protocol included the common femoral, superficial femoral, and popliteal veins. If the indication was calf swelling or pain, the calf veins were also examined.

All cases were retrospectively reviewed by two musculoskeletal radiologists, with 8 and 7 years of post-fellowship experience respectively (BKH, EYC). The MRI examinations findings recorded included: the presence and pattern of edema, classified as either perivascular intermuscular (Fig. 1) or intramuscular (Fig. 2), segmental vein dilation (Fig. 3), the presence or absence of focally altered intraluminal signal on fluid-sensitive sequences (Fig. 4), and if performed, abnormal hyperintense intraluminal signal on axial T1-weighted sequences (Fig. 5). The presence and extent of thrombus (i.e., IMCVT with or without extension into the popliteal vein) was assessed. The ultrasound evaluations by the musculoskeletal radiologists were compared with the initial interpretation at the time of the examination. Data were evaluated using Microsoft Excel 2016 (Microsoft Corporation, Seattle, WA, USA) using the "N-1" Chi-squared test, as recommended by Campbell [15]. For patients who had positive examinations at the time of initial evaluation, charts were reviewed for clinical management of the IMCVT, with attention being paid to changes that may affect the coagulation profile and complications related to the presence of IMCVT, if available, were recorded.

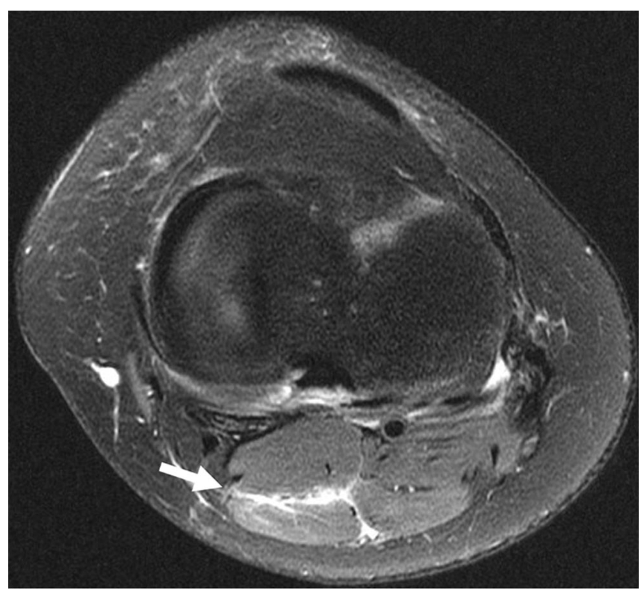

Fig. 1 Presence and pattern of edema: perivascular intermuscular edema. A 32-year-old woman who felt a "pop" during Pilates. An axial proton density (PD)-weighted fat-suppressed (FS) axial image demonstrates the presence of perivascular edema within the intermuscular fat planes (*arrow*). The assessment was subjective and designations were not exclusive. In this case, there is concomitant perivascular intramuscular edema

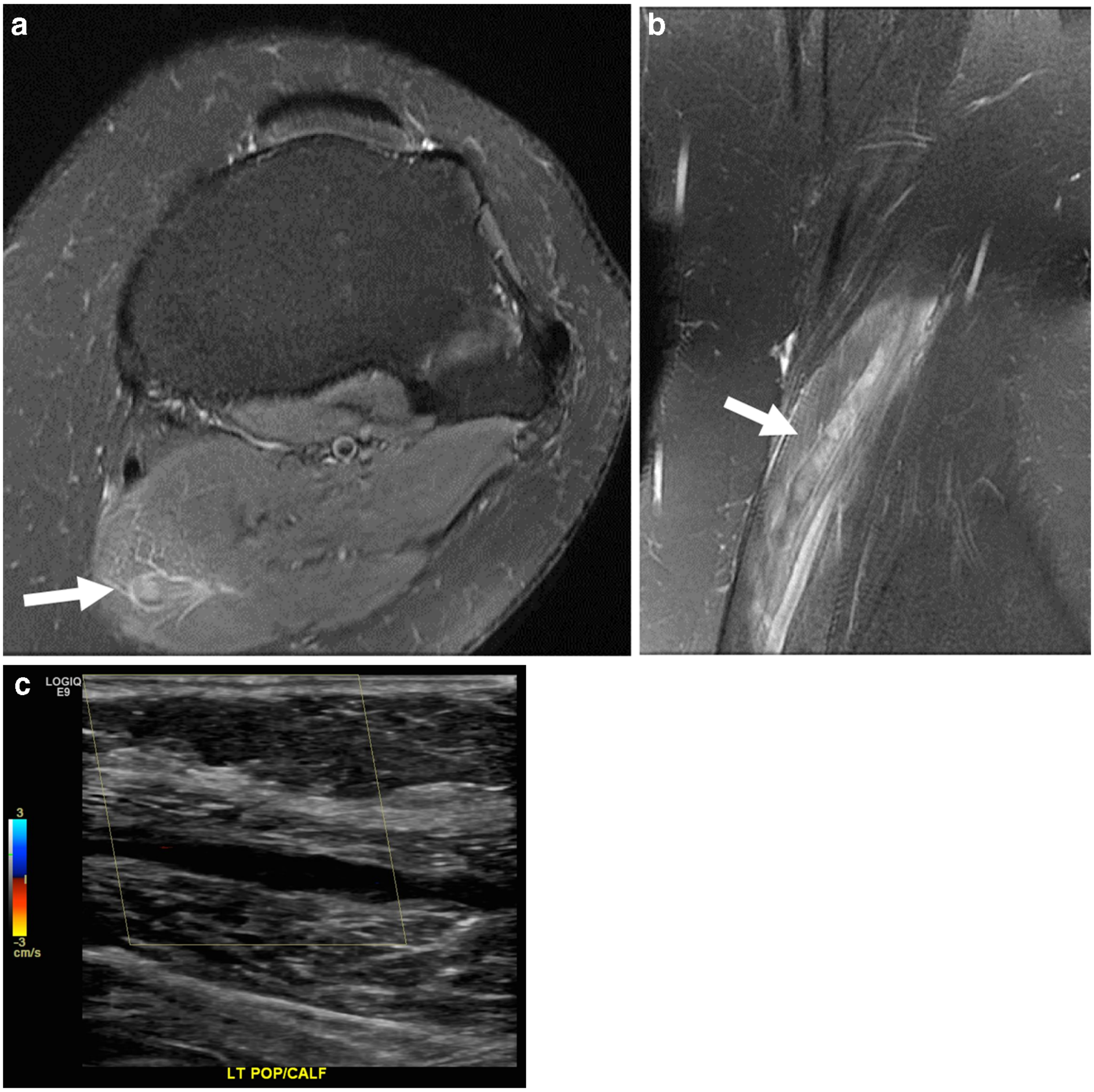

Fig. 2 Presence and pattern of edema: intramuscular edema. Same patient as Fig. 1. **a** Axial and **b** coronal PD-weighted FS sequences demonstrate an intramuscular distribution of edema (*arrows*) in the vicinity of the vein. The assessment was subjective and designations were not exclusive. **c** Subsequent confirmatory ultrasound evaluation demonstrates intramuscular calf vein thrombosis (IMCVT) within the popliteal vein and an intramuscular calf vein, as demonstrated by the absence of color flow on Doppler imaging and noncompressibility of the vein (not shown)

Results

A total of 67 patients underwent knee MRI and duplex ultrasound examinations within 14 days of one another. Patient demographics are listed in Table 1. Thirteen patients had positive ultrasound examinations for IMCVT, 3 of whom had central extension into the popliteal vein (23%), and 10 of which had no central extension (77%). The indications for the MRI examinations for those with positive studies were trauma, including motor vehicle accident ($n = 11$), and chronic knee pain ($n = 2$). The indications for the MRI examinations for the 54 patients with negative DVT studies were chronic knee pain ($n = 25$), knee joint effusion ($n = 4$), knee pain with effusion or instability ($n = 10$), trauma ($n = 9$), calf swelling ($n = 2$), knee mass ($n = 3$), and nerve injury ($n = 1$). All positive cases of IMCVT involved the medial head of the gastrocnemius vein, and 1 case also involved the soleal vein. There was no involvement of the lateral head of the gastrocnemius vein in any of the cases. Ultrasound was performed after MRI in 10 cases (mean = 2.2 days) and was performed before MRI in 3 cases (mean = 6.3 days). All MRI examinations performed before the ultrasound prospectively identified the IMCVT and made recommendations to confirm the findings with ultrasound. Nine patients with positive and 53 patients with negative ultrasound examinations had axial T1-weighted sequences included on the MRI examination.

Of the 13 patients with positive ultrasound examinations, all 13 (100%) had perivascular intermuscular edema, 10

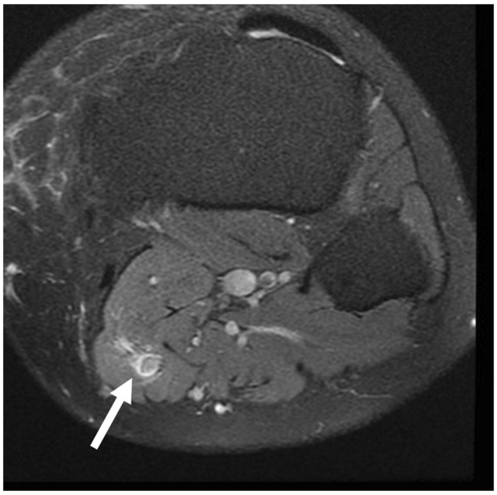

Fig. 3 Presence or absence of segmental vein dilation. A 33-year-old woman with knee instability and locking following a motor vehicle accident. An axial PD-weighted FS image demonstrates the presence of focal vein dilation (*arrow*), subjectively assessed. Also note the presence of adjacent intramuscular edema and abnormal intraluminal signal

(77%) had intramuscular edema, 12 (92%) had focal vein dilation, and 10 (77%) had abnormal intraluminal signal on fluid-sensitive MRI sequences. Conversely, of the 54 patients with negative ultrasound examinations, 4 (7%) had perivascular intermuscular edema, 6 (11%) had intramuscular edema, 10 (19%) had focal vein dilation, and 2 (4%) had abnormal intraluminal signal on fluid-sensitive sequences. Of the 13 positive studies, 9 had axial T1-weighted sequences included, and 4 of those (44%) had abnormal, mildly hyperintense intraluminal T1-weighted signal in the vessel. Of the 54 negative studies, 53 had axial T1-weighted sequences included, and 1 (2%) of those had abnormal, mildly hyperintense intraluminal T1-weighted signal in the vessel.

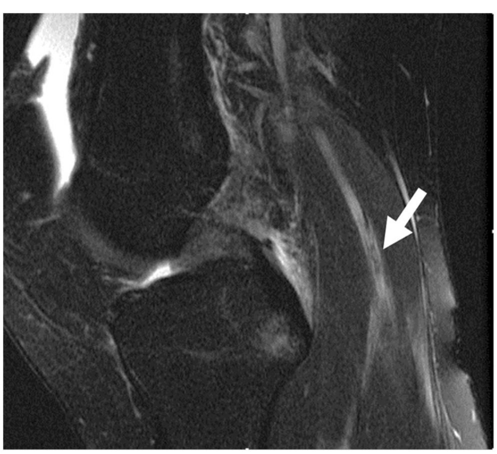

Fig. 4 Presence or absence of focally altered intraluminal signal. A 24-year-old woman with knee pain following injury while dancing. A sagittal T2-weighted FS image demonstrates focally altered signal within the venous lumen (*arrow*), which has the appearance of a filling defect. The assessment was subjective

When comparing patients with positive and negative ultrasound examinations, there were significant differences in each of these parameters: perivascular intermuscular edema (100% vs 7%, $p = <0.0001$), intramuscular edema (77% vs 11%, $p = <0.0001$), focal vein dilation (85% vs 19%, $p = <0.0001$), abnormal intraluminal signal on fluid-sensitive sequences (77% vs 4%, $p = <0.0001$), and abnormal hyperintense T1-weighted signal (44% vs 2%, $p = 0.0001$). The diagnostic performance of each parameter is listed in Table 2. The sensitivity of the various findings ranged from 77 to 100% and the specificity ranged from 82 to 96%. Overall, the presence of all four findings yielded sensitivity of 62% and specificity of 98%.

In the 10 cases of IMCVT *without* central extension, the original diagnostic radiology ultrasound reports were as follows: 4 (40%) "intramuscular vein thrombosis, but *no evidence* of DVT"; 2 (20%) "intramuscular vein thrombosis, *with no* popliteal vein extension" with no specific mention of the presence or absence of DVT; 2 (20%) "occlusive thrombosis of a calf vein without DVT"; and 2 (20%) "superficial vein thrombosis, with no evidence of DVT." Three of these patients underwent computed tomographic pulmonary angiogram and 1 (10%) study was positive for pulmonary thromboembolism. All 3 cases of IMCVT *with* central extension were reported as positive for "DVT" on the corresponding ultrasound reports. The clinical management of the 13 patients with IMCVT were varied and are listed in Table 3. All cases of IMCVT with central extension were treated with full-dose anticoagulation.

In the patients with popliteal vein extension of the IMCVT ($n = 3$) compared with those without DVT ($n = 54$), there was a statistically significant increase in peripopliteal edema ($n = 3$ vs 18, 100% vs 33%, $p = 0.046$) and abnormal fluid-sensitive signal within the vein ($n = 3$ vs 1, 100% vs 2%, $p = 0.0001$). There were no cases of focal popliteal vein dilation in the cohort with central extension of IMCVT into the popliteal vein, but there were 2 cases of focal popliteal vein dilation in the cohort without central extension (0% vs 4%, $p = 1.000$), a difference that was not statistically significant.

In the patients with IMCVT with popliteal vein extension ($n = 3$) compared with those with IMCVT without popliteal DVT ($n = 10$), there was a statistically significant increase in peripopliteal edema ($n = 3$ vs 3, 100% vs 30%, $p = 0.040$). There was no significant difference between segmental calf vein dilation ($n = 3$ vs 9, $p = 0.584$), intramuscular edema ($n = 2$ vs 8, $p = 0.629$), or abnormal fluid-sensitive signal within the calf vein ($n = 2$ vs 8, $p = 0.652$). There were no instances of segmental popliteal vein dilation in either cohort. All cases of isolated IMCVT with and without popliteal vein extension demonstrated perivenous edema.

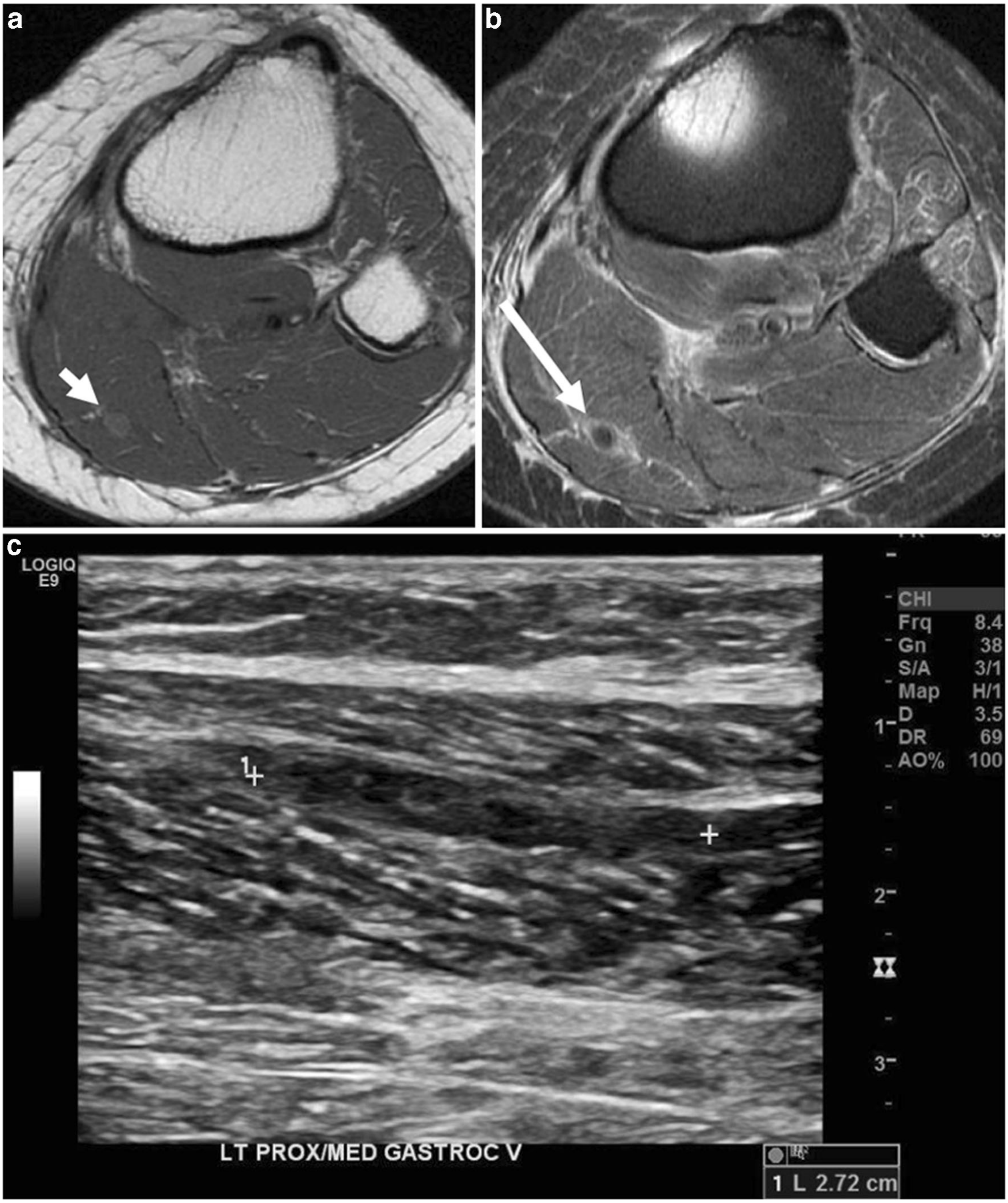

Fig. 5 Presence of abnormal hyperintense signal on axial T1-weighted sequences. A 47-year-old woman with 1 month of increased knee pain and swelling. **a** An axial T1-weighted image demonstrates subtly abnormal high signal intensity within the venous lumen (*short arrow*) that correlates with **b** focally abnormal signal on the axial PD-weighted FS image (*long arrow*). **c** Subsequent confirmatory ultrasound evaluation demonstrates the IMCVT. In this case, the medial head of the gastrocnemius vein was involved, as demonstrated by noncompressible echogenic intraluminal material (bordered by +)

Discussion

The current study reports findings on routine unenhanced MRI examinations of the knee that may indicate underlying IMCVT, a cause of pain and possible source of morbidity. Overall, the data support the findings of perivascular and intramuscular edema, focal venous dilation, and abnormal fluid-sensitive signal within the vein as markers for IMCVT. One must take all the findings and clinical history into careful consideration, as the MRI muscle findings, in particular intramuscular edema, have been reported with other traumatic (i.e., muscle strain, contusion, delayed-onset muscle soreness, and

Table 1 Patient demographics

	IMCVT (+)	IMCVT (−)	Total
Number of patients (*n*)	13	54	67
Male	4	24	28
Female	9	30	39
Right	5	24	29
Left	8	30	38
Age (years), mean (range)	39.5 (19–60)	53.1 (22–80)	50.4 (19–80)

IMCVT intramuscular calf vein thrombosis

compartment syndrome) and atraumatic (i.e., inflammatory/autoimmune conditions, denervation, infections, and ischemia) causes [16, 17].

In cases when IMCVT is detected, lack of familiarity on the part of the radiologist may lead to erroneous reporting of these as superficial vein thromboses rather than true DVTs. This was evident in our study. In the 10 cases of IMCVT *without* central extension, there was varied reporting with 75% of reports *mischaracterizing* the isolated IMCVT, whereas all 3 cases of IMCVT *with* central extension were accurately reported as "DVT." This study affirms the point that although radiologists may be familiar with the central deep veins, they may be unfamiliar with the smaller tributaries of the deep veins, their classifications, and their nomenclature. This may be due to the limited evaluation of intramuscular veins on ultrasound. This unfamiliarity leads to confusion for the clinician, who may elect not to treat solely based on the radiologist's report, rather than determine optimal treatment based on careful risk–benefit analysis.

The appropriate clinical management regarding IMCVT remains controversial and most patients in our cohort received individualized therapy based on a number of factors. Multiple studies within the past decade have evaluated the role of anticoagulation in the setting of IMCVT with varied results, although most demonstrate a decreased risk of venous thromboembolism and increased bleeding risk with unclear risk–benefit profiles (Table 4) [18–25]. Thus, the assumption that calf vein thrombi are clinically insignificant may play a role in the under-recognition of IMCVT on ultrasound. Lack of time, lack of reimbursement, exclusion of the calf veins by protocol, or lack of sonographer training may also contribute to the relatively low sensitivity of IMCVT on ultrasound. One of the 10 patients with isolated IMCVT in our study group (10%) was diagnosed with a pulmonary embolism. In the literature, the rates of pulmonary embolism in patients with IMCVT have been reported to range from 0 to 31% [20].

A curious finding in this investigation was that all cases involved the medial head of the gastrocnemius vein, whereas none involved the lateral head of the gastrocnemius vein. The reason for this is not understood. One can only conjecture whether these veins are more prone to injury or venous stasis. Perhaps thrombosis within the lateral head does occur, but was simply not detected in our study. These results do suggest that specific interrogation of the medial head of the gastrocnemius

Table 2 Ratio, percentage, sensitivity, specificity, positive predictive value (*PPV*), and negative predictive value (*NPV*) of each parameter studied

	Ratio (%) in IMCVT-positive studies	Ratio (%) in IMCVT-negative studies	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Perivascular intermuscular edema	13/13 (100)	4/54 (7)	100	93	76	100
Intramuscular edema	10/13 (77)	6/54 (11)	77	89	63	94
Focal vein dilation	12/13 (92)	10/54 (19)	92	82	55	98
Abnormal intraluminal signal (PD- or T2-weighted)	10/13 (77)	2/54 (4)	77	96	83	95
All parameters present	8/13 (62)	1/54 (1)	62	98	89	91

IMCVT intramuscular calf vein thrombosis, *PD* proton density

Table 3 The clinical management of patients who had IMCVT discovered on routine MRI

Management	Number of patients (*n* = 13)
No therapy, conservative Management, *n* (%)	3 (23)
Discontinuation of oral contraceptive pill, *n* (%)	1 (8)
Full-dose aspirin (325 mg), *n* (%)	4 (31)
Full-dose anticoagulation (coumadin/low molecular weight heparin/novel anticoagulants, *n* (%))[a]	5 (38)

[a] Refers to one patient with a positive computed tomographic pulmonary angiogram for pulmonary embolism

Table 4 Summary of studies evaluating the management and the role of anticoagulation therapy in the setting of IMCVT

Reference	Number of cases	Study design/treatment arms	Results
Sule et al. [18]	51 patients	Retrospective cohort/anticoagulation versus no treatment	Distal DVT may not require treatment with anticoagulation. If leg symptoms worsen, or if there is an extension of distal DVT on the follow-up scan, treatment with anticoagulation is recommended
Masuda et al. [19]	31 papers	Systematic review	Grade IIB evidence for either anticoagulation for an undetermined duration or observation with elastic support and surveillance imaging studies
De Martino et al. [20]	454 patients (pooled from 6 papers)	Meta-analysis/anticoagulation versus no treatment	Anticoagulation therapy for calf vein DVT may decrease the incidence of PE and thrombus propagation. Evidence limited by poor methodological quality and few events
Utter et al. [21]	384 patients	Retrospective cohort/anticoagulation versus no treatment	Therapeutic anticoagulation is associated with a one-third reduction of proximal DVT and PE, but an increase in bleeding
Righini et al. [22]	259 patients	Randomized, double-blind, placebo-controlled/ low molecular weight heparin versus placebo	LMWH did not reduce the risk of proximal extension or thromboembolic events in low-risk symptomatic outpatients, but did increase the risk of bleeding

DVT deep vein thrombosis, *PE* pulmonary embolism, *LMWH* low molecular weight heparin

vein should be performed, particularly in patients who have suspicious ancillary findings on MRI.

Although our results demonstrated statistical significance, these conclusions may be limited, as this is a retrospective study with a small sample size. As a retrospective study, cases may have been missed by the database search or by interpreting radiologists at the time of the initial examinations. Additional limitations include subjective assessment of the MRI findings, especially with regard to intraluminal signal abnormalities and vein dilatation. In the senior author's experience, focal segmental areas of intramuscular vein dilatation are commonly seen on routine knee MRI examinations in patients with no other ancillary findings to suggest IMCVT. In addition, the signal intensity within a patent vein can vary greatly and is dependent on myriad factors. These encompass the presence of turbulence, which is greater in the central portion of veins, around valves, and areas of caliber change, including bifurcations [26]. Signal intensity is also affected by the obliquity of the vessel to the imaging plane in addition to the direction of the imaging stack relative to venous flow (cocurrent or countercurrent) [27, 28]. Moreover, as a retrospective study, most of the MRI studies did not include the entirety of the deep venous system of the calf, which may have led to an inadvertent increase in false-negative examinations.

In conclusion, imaging findings on routine unenhanced MRI have a high rate of concordance with duplex ultrasound performed through the calf in the detection of IMCVT, including perivascular intermuscular edema, intramuscular edema, focal vein dilation, and abnormal intraluminal signal on either fluid-sensitive or T1-weighted sequences. When these findings are demonstrated in the calf on a routine knee MRI, the data suggest that a DVT might be the cause and that an ultrasound evaluation of the calf veins should be recommended for confirmation. Despite ongoing controversy regarding the clinical significance and management of isolated IMCVT, accurate reporting and detection remain important for clinical decision-making. The medial head of the gastrocnemius vein appears to be preferentially involved for reasons that are not entirely clear, and perhaps this occurrence could be better understood with studies with larger patient cohorts.

Compliance with ethical standards

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

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