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Original article

Identification and differentiation of gluteus medius tendon pathology using ultrasound and magnetic resonance imaging

Sean Iain Docking[a,*], Jill Cook[a], Stephanie Chen[f], Jennie Scarvell[b], Wes Cormick[c], Paul Smith[d,e], Angela Fearon[b,g]

[a] La Trobe Sports and Exercise Medicine Research Centre, La Trobe University, Bundoora, 3086, Australia
[b] Discipline of Physiotherapy, Faculty of Health, University of Canberra, Canberra, 2617, Australia
[c] Canberra Specialist Ultrasound, Canberra, 2617, Australia
[d] Division of Surgery, The Canberra Hospital, Canberra, 2605, Australia
[e] College of Medicine and Health Sciences, Australian National University, Canberra, 0200, Australia
[f] Canberra Imaging Group, Canberra 2600, Australia
[g] Research Institute for Sport and Exercise, University of Canberra, 2617, Australia

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ABSTRACT

Background: It has been suggested that imaging findings play a role in directing treatment for Greater Trochanteric Pain Syndrome. Structural diagnoses associated with Greater Trochanter Pain Syndrome include gluteal tendinosis, and partial- or full-thickness gluteal tendon tears. However, few studies have compared imaging to confirmed tendon pathology observed during surgery.
Objective: To investigate the ability of magnetic resonance and ultrasound imaging to identify the presence of a pathological gluteus medius tendon in comparison to surgical and histological findings.
Study design: Cross-sectional study.
Methods: 26 participants undergoing gluteal tendon reconstruction surgery or hip arthroplasty were included. Prior to surgery, participants underwent both magnetic resonance (MR) (n = 23) and ultrasound (US) (n = 25) imaging. A radiologist (MR) and nuclear physicians (US) classified the gluteus medius tendon as normal, tendinosis (no tear), partial-thickness tear, or full-thickness tear.
Results: Ultrasound identified 17 out of the 19 pathological gluteus medius tendons correctly. However, 5 of the 6 normal tendons were incorrectly identified as exhibiting pathology on ultrasound. Magnetic resonance rated 11 out of 17 pathological tendons as abnormal, with 4 out of 6 normal tendons identified correctly. Both imaging modalities were poor at identifying and differentiating between tendinosis and partial-thickness tears.
Conclusion: Both imaging modalities showed a reasonable ability to identify tendon pathology. While limited by sample size, these early findings suggest that both imaging modalities may be limited in identifying specific pathoanatomical diagnoses, such as partial-thickness tears. These limitations may misdirect treatment.

1. Introduction

Magnetic resonance (MR) and ultrasound (US) imaging are diagnostic tools that inform clinical practice. In Australia, there was an 89% increase in hip US studies in the financial year 2015–16 compared to 5 years previously, with a cost of approximately $25 million in that year (Department of Health Services, Australian Government). Decreases in the cost of imaging services, improvements in imaging technology, and increased access have led to its increased use in clinical practice. Despite the substantial increase in the use of imaging, the diagnostic accuracy of imaging modalities have been questioned, specifically the ability to identify structural pathologies (Brinjikji et al., 2015; Hart et al., 2017; Docking et al., 2015; McAuliffe et al., 2016; De Maeseneer et al., 2009).

Greater trochanteric pain syndrome (GTPS) is a common condition of the hip, characterised by lateral hip pain, dysfunction and decreased quality of life (Segal et al., 2007; Fearon et al., 2014a). While GTPS diagnoses are made from clinical criteria, imaging is used to aid diagnosis and the planning of treatment (Long et al., 2013). However, ultrasound findings for GTPS bear little relation to symptoms (De Maeseneer et al., 2009), consistent with other musculoskeletal conditions (eg non-specific lower back pain (Brinjikji et al., 2015), knee

* Corresponding author. La Trobe Sport & Exercise Medicine Research Centre, La Trobe University, Bundoora, VIC 3086, Australia.
E-mail address: s.docking@latrobe.edu.au (S.I. Docking).

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degenerative changes (Hart et al., 2017), Achilles and patellar tendinopathy (McAuliffe et al., 2016)). A number of studies have reported a high prevalence of gluteal tendon pathology in asymptomatic hips, with up to 50% of hips demonstrating gluteal tendinosis or a partial gluteal tear (Blankenbaker et al., 2008; Woodley et al., 2008; Bird et al., 2001; Ganderton et al., 2017). However, few studies have looked at the diagnostic accuracy of these imaging modalities to identify and differentiate structural pathologies of the gluteal tendons.

Structural diagnoses associated with GTPS include trochanteric bursitis, gluteal tendinosis, and partial- or full-thickness gluteal tendon tears (Long et al., 2013; Connell et al., 2003; Dwek et al., 2005). Differentiation of these pathologies is challenging due to the morphology of the structures over the greater trochanter and the extensive overlying adipose tissue. Westacott et al. (2011) reported the diagnostic accuracy of imaging compared to surgery in identifying gluteal tears, finding that US was superior to MR imaging (sensitivity = 79–100% & 33–100%, for US and MR imaging respectively). However, this study focused on gluteal tears and did not include tendinosis, nor differentiate between partial- or full-thickness tears. The limited ability of imaging to differentiate tendinosis and partial-thickness tears has been reported in the Achilles tendon and rotator cuff tendons of the shoulder (Roy et al., 2015; Paavola et al., 1998).

The primary aim of this study was to investigate the ability of MR and US imaging to identify partial- or full-thickness gluteus medius tendon tears or tendinopathy in comparison to surgical and histological findings. We hypothesised that both imaging modalities would be able to identify these pathologies in the gluteus medius tendon.

2. Methods

2.1. Participants

Participants were recruited as part of a larger study (Fearon et al., 2013, 2014a, 2017). In brief, participants were prospectively recruited between July 2007 and August 2009. Participants were women aged over 18 years who spoke English. The first group included those with refractory lateral thigh pain over the greater trochanter who had failed conservative treatment (physiotherapy and corticosteroid injections) and with tendon tearing observed on either US or MR imaging. This group was drawn from a waiting list for gluteal tendon reconstruction surgery (GTR). Participants in the GTR group were excluded if they had clinical or radiological evidence of hip osteoarthritis according to published guidelines (Altman et al., 1991). The second group included women age-matched to the GTR group but with clinical and radiological signs of hip osteoarthritis (OA) (Altman et al., 1991) and drawn from a waiting list for primary hip arthroplasty surgery. The OA group excluded those with clinical symptoms of lateral thigh pain or pain on palpation of the greater trochanter.

Both groups excluded those with lumbar spine nerve root signs or symptoms, past history of lumbar spine or ipsilateral leg surgery, systemic inflammatory disease or osteogenic disease (eg Paget's disease).

Clinical data relating to these participants have been published previously (Fearon et al., 2014a, 2017). Clinical data was not included as the current study is investigating the diagnostic accuracy of imaging in the identification of structural pathologies, independent of clinical symptoms.

Ethical approval was gained from the relevant university and hospital human research ethics committees where the research was conducted prior to the commencement of the study.

2.2. Imaging data collection

Participants underwent MR and US imaging prior to surgery. The clinicians providing the reports (radiologist (MR) and nuclear physicians (US)) were blinded to all clinical tests, and the proposed side and type of surgery.

MR imaging was undertaken using a Phillips (N.V.) 1.5 T MR scanner. 4 mm slices were generated from axial, coronal and sagittal views of T2 sequences, with and without fat saturation, and coronal T1 images (Appendix S1). Each MR study was examined by an experienced radiologist with a special interest in musculoskeletal imaging. The radiologist was provided with a copy of Pfirrmann et al. (2001) which provides examples of gluteus medius tendon deficits, and asked to use this as a reference for reporting their findings (Appendix S2). The radiologist was involved in developing this standardised proforma.

Ultrasound imaging was undertaken on an Advanced Technology Laboratory 5000 US (Advanced Technology Laboratories; Seattle, USA) with 7 MHz probe. The ultrasound examination was undertaken by one of two nuclear physicians with post-graduate training in sonography. These physicians jointly undertook a training session, used the same protocol to obtain the images, and were provided with a copy of Connell et al. (2003) as a reference standard. Due to unforeseen and unavoidable circumstances, physician one examined the first 30% of participant's images and physician two examined the remainder. For analysis, the reports from both nuclear physicians were collated together and termed 'US'.

To develop the MR, US and surgical data collection forms, two researchers, the surgeons and physicians identified key elements from de-identified existing reports and the current literature (Appendix S3). The gluteus medius tendon for each assessor was classified as either normal, tendinosis without a tear, partial-thickness tear or full-thickness tear. A full-thickness tear did not necessarily mean a complete loss of continuity of tendon fibres (Connell et al., 2003; Pfirrmann et al., 2001, 2005; Kingzett-Taylor et al., 1999; Lequesne et al., 2008; Kong et al., 2007).

2.3. Surgical data collection

Patients underwent surgery within 3 weeks of imaging. Surgery was performed by one of three orthopaedic surgeons (24, 3, and 2 surgeries, respectively). Surgeons were asked to provide an assessment on the state of the tendon during surgery (Appendix S4).

Surgeons who performed GTR were not blinded to imaging reports, as the presence of a gluteal tendon tear on US or MR imaging was an indication for surgery. The surgeons and researchers were blinded to the tendon imaging reports for participants having THA.

2.4. Tissue collection and histological analysis

Tendon tissue collection and processing has previously been described (Fearon et al., 2014b). Briefly, samples of gluteus medius tendon were collected as a central strip of the tendon at the time of surgery. Samples were fixed in 10% buffered formalin, then processed and embedded in paraffin using standard laboratory procedures. The tendon was stained with haematoxylin and eosin (H&E) and Alcian Blue. Slides were evaluated using the Bonar score (Fearon et al., 2014c); a categorical evaluation of histopathological changes generating a score 0–15, with 0 indicating normal tendon structure. This was performed by two researchers blind to the study group and surgical findings. Any disagreement was resolved by a third researcher. Researchers used a reporting proforma with reference slides available for calibration (Fearon et al., 2014c). Researchers 1 and 3 had specialist training in histopathology. Researcher 2 was a higher degree student trained by researchers 1 and 3. Researchers 1 and 2 had an inter-tester reliability of $r^2 = 0.71$ (Fearon et al., 2014c).

2.5. Data analysis

Findings from imaging modalities were compared to surgical and histological findings. Tendon abnormality was determined by findings from surgery and histopathology (either partial- or full-thickness tear observed during surgery or a Bonar score > 5 indicating gluteus medius

tendon pathology). Healthy tendon was determined by no observable tear during surgery and a Bonar score less than 5. Statistical analysis was undertaken using MedCalc (Version 17.4). A series of 2 × 2 contingency tables were generated. Accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and 95% confidence intervals (CI) were calculated for each test condition (ie MR and US). Post-test probabilities were calculated as likelihood ratios (LR). The likelihood ratios account for a shift in the probability of the condition being present if the test is positive or negative, therefore, providing a more clinically relevant indicator of the utility of this test. Likelihood ratios were considered significant ($p < 0.05$) if the 95% CI did not contain 1.

Due to limited sample size, contingency tables were not performed for specific structural pathologies, but descriptive analysis is presented. The criteria for these structural pathologies included tendinosis in the absence of any tear (determined by a Bonar score > 5 and no tear observed during surgery), partial-thickness or full-thickness tear (reported during surgery).

Participants who did not undertake a specific test condition (either MR or US) were excluded from the statistical analysis of the diagnostic accuracy for that imaging modality.

3. Results

Twenty-nine participants were recruited. One participant was excluded because data was not obtained during surgery and two participants were excluded due to missing histology results. Therefore, 26 participants were included for analysis (GTR = 11; THA = 15). Three participants had missing MR reports and one participant did not undertake US imaging (Table 1). At surgery, 20 of the 26 participants demonstrated pathological tendons. Nine participants had gluteus medius tendinosis with no tear, five participants had partial-thickness tears, and six participants had with full-thickness gluteus medius tears.

Table 1
Participant's age, the surgical procedure, imaging modality used and the Bonar score of their tendon sample at histology.

ID	Age	Surgical procedure	MR	US Reader	Histology
					Bonar score
1	68.1	GTR	.	NP1	13
2	47.6	GTR	.	NP1	10
3	77.3	GTR	.	NP1	11
4	36.6	GTR	Y	NP1	13
5	63.1	GTR	Y	NP1	9
6	50.4	GTR	Y	NP2	14
7	51.8	GTR	Y	NP2	4
8	66.5	GTR	Y	NP2	7
9	63.6	GTR	Y	NP2	8
10	41.7	GTR	Y	NP2	6
11	64.4	GTR	Y	NP2	11
12	63.9	THA	Y	NP1	11
13	59.1	THA	Y	NP1	10
14	50.8	THA	Y	NP2	1
15	45.8	THA	Y	NP1	0
16	41	THA	Y	.	14
17	71.8	THA	Y	NP2	11
18	82.7	THA	Y	NP2	7
19	75.2	THA	Y	NP2	8
20	57.3	THA	Y	NP2	2
21	43.2	THA	Y	NP2	13
22	57.4	THA	Y	NP2	0
23	81.3	THA	Y	NP2	6
24	55	THA	Y	NP2	7
25	45.7	THA	Y	NP2	5
26	68.2	THA	Y	NP2	10

NP1 = WC, NP2 = RG.
Note: GTR: Gluteal tendon reconstruction, THA: total hip arthroplasty. MR: Magnetic resonance imaging. NP1: Nuclear physician 1, NP2: Nuclear physician 2.

Table 2
Diagnostic utility of various imaging modalities in the diagnosis of any gluteus medius tendon pathology (tendinosis, partial- or full-thickness tear) using surgery/histopathology as the reference standard.

Diagnosis	MR Imaging	Ultrasound
True +	11	17
True -	4	1
False +	2	5
False -	6	2
Sensitivity	64.7% (38.3–85.8)	89.5% (66.9–98.7)
Specificity	66.7% (22.3–95.7)	16.7% (0.4%-64.1)
PPV	84.6% (62.1–94.7)	77.3% (69.7%-83.4)
NPV	40.0% (22.1–61.1)	33.3% (5.2–82.1)
LR+	1.94 (0.59–6.35)	1.07 (0.73–1.59)
LR-	0.53 (0.22–1.25)	0.63 (0.07–5.80)
Accuracy	65.2%	72.0%

PPV: Positive predictive value; NPV: Negative predictive value; LR+: positive likelihood ratio; LR-: Negative likelihood ratio.

Magnetic resonance imaging correctly identified 11 out of the 17 pathological gluteus medius tendons and 4 out of 6 structurally normal tendons. Diagnostic accuracy measures were calculated and reported in Table 2. However, caution is advised in interpreting these diagnostic accuracy measures due to the small sample size resulting in wide 95% confidence intervals.

Ultrasound identified a pathological tendon correctly in 17 of 19 pathological gluteus medius tendons (either tendinosis, partial- or full-thickness tear) imaged. However, ultrasound had a tendency to over-report the presence of tendon pathology, where 5 of the 6 structurally normal tendons were incorrectly reported as pathological.

Imaging identification of specific pathological findings are outlined in Table 3. Both imaging modalities demonstrated difficulty in identifying/differentiating between the presence of tendinosis, partial thickness tears, and full-thickness tears. Both modalities were able to rule out the presence of a full-thickness tear in almost all cases. However, it needs to be stated that MR did not identify the presence of a full-thickness tear in any case. Of the false positives for either tendinosis or partial-thickness tears, the majority of cases were the contrasting diagnosis (MR-44.5%, US-42.9%). Similarly, of the false negatives of either tendinosis or partial tears, the majority of cases were the contrasting diagnosis (MR – 44.5%, US-66.7%).

4. Discussion

This study demonstrated that both MR and US imaging have variable ability to identify a pathological gluteus medius tendon observed during surgery or via histology. Magnetic resonance imaging had a number of false negatives suggesting that MR tended to under-report the presence of pathology, whereas US had a tendency to over-report the presence of pathology, indicated by the number of false positives. Both imaging modalities were poor at differentiating the specific

Table 3
The proportion of true positive and negatives and false positive and negatives for MR imaging and ultrasound in the identification of tendinosis, partial-, or full-thickness tear using surgery/histopathology as the reference standard.

Diagnosis	True +	True -	False +	False -
Tendinosis with no tear				
MR imaging	2	11	3	7
Ultrasound	2	12	5	6
Partial-thickness tear				
MR imaging	2	13	6	2
Ultrasound	2	11	9	3
Full-thickness tear				
MR imaging	0	19	0	4
Ultrasound	3	18	1	3

pathological diagnosis such as tendinosis, partial-thickness tears, and full-thickness tears.

Our study concurs with the systematic review by Westacott et al. (2011) in demonstrating that US has superior diagnostic accuracy compared to MR imaging in identifying gluteal tendon pathology. However, caution is needed in interpreting these studies. Prior to this study, the largest study included 24 participants (Fearon et al., 2010) and all of the studies reviewed by Westacott had a high risk of bias. Consequently, although 95% CI's were not reported, they were likely to have been large due to the small sample size. Furthermore, only one previous study included a group of participants with structurally normal tendons (n = 6) (Cvitanic et al., 2004). The inclusion of structurally normal tendons was important, as the rate of false positives is as important as the rate of true positives. Normal tendons being incorrectly identified as pathological may lead to patients receiving inappropriate and unnecessary treatments due to misdiagnosis.

This study is the first to report imaging findings based on the identification of tendinosis, partial-, and full-thickness tears, separately. It needs to be stated that the relative sample size in each group is low, due to the difficulty in recruiting participants and standardising measures, which limits interpretation of the findings. Both MR and US imaging have questionable ability to identify these specific structural pathologies. Previous studies have shown that US has a limited ability to discriminate between tendinosis and partial-thickness tears (Connell et al., 2003; Fearon et al., 2010). Lindner et al. (2015) identified 11 patients with tendinosis in the absence of a tear using magnetic resonance angiogram, yet all patients were shown to have a partial- or full-thickness tear during surgery. Interestingly, this is not just a limitation for imaging of the gluteus medius tendon. In the rotator cuff, a systematic review by Roy et al. (2015) found that both MR and US imaging had a limited ability to detect partial-thickness tears (sensitivity = 43% (95% CI 16–76%) and 64% (95% CI 32–88%), respectively) when studies with a low risk of bias were analysed. Paavola et al. (1998) reported that US was limited in differentiating between a partial tear and a degenerative lesion in the Achilles. Taken together with previous findings, these pilot findings warrant a more highly powered study.

A limitation of identifying pathology and specific structural diagnoses is that conventional imaging modalities rely on radiological interpretation. Different imaging features have been used to differentiate tendinosis, partial- and full-thickness tears, such as the extent of pathology (hypoechogenecity on US or high signal on T2 MR imaging), discontinuity of tendon fibres, and thinning/elongation of the tendon (Connell et al., 2003; Lequesne et al., 2008; Kong et al., 2007; Chi et al., 2015). However, to our knowledge there is no consensus around the features that differentiate these structural diagnoses. This lack of consensus, and the resultant inability to reliably distinguish between the various categories may contribute to poor accuracy.

The relationship between pain and pathology has not been investigated in GTPS. In the shoulder, multiple studies have shown that rotator cuff tear size does not correlate with severity of pain or duration of symptoms (Wylie et al., 2016; Unruh et al., 2014; Dunn et al., 2014). Due to a lack of prognostic studies, it is unclear whether patient's response to various treatments (ie exercise, injection, surgery etc) differs based on the presence of tendinosis, partial-thickness tears, or full-thickness tears. Future studies are needed to demonstrate the reliability and accuracy of imaging in identifying the presence the pathological states stated in this paper. Until then, these terms may need to be avoided when reporting on MR or US imaging as they are clinically unimportant and may cause patients undue distress (Schenk, 2008). Until better diagnostic criteria are generated and tested, these diagnoses should simply be termed as an ‘intra-tendinous pathology’.

The inclusion of participants with normal gluteal tendons was a strength of this study, as it allowed for the calculation of diagnostic accuracy, such as specificity, NPV, and likelihood ratios). While the original study design was case-control, risk of bias was minimised somewhat as inclusion of participants in the current diagnostic accuracy study was made irrespective of the participants' surgical findings and blinded to the reference standard (ie surgical findings).

This is the largest study that has compared imaging to surgical findings for the gluteus medius tendon. This study was further strengthened as it directly compared MR and US imaging to determine the imaging modality of choice in the diagnosis of structural pathology of the gluteus medius tendon. A limitation of this study was that the nuclear physician reporting on US imaging changed part way through the study. However, both nuclear physicians used the same scanning technique and diagnosis guidelines. Similarly, multiple surgeons were used to assess surgical findings, however all were experienced surgeons. Another limitation of this study was that the US frequency and MR field strength were low compared to contemporary machines. Some authors have suggested that newer machines with greater image resolution provide superior differentiation of various structural pathologies. However, a systematic review in rotator cuff tendon pathology showed that greater US transducer frequency and MR field strength did not affect diagnostic accuracy (Roy et al., 2015).

5. Conclusion

Magnetic resonance and ultrasound imaging may be adequate to differentiate pathological or normal gluteus medius tendon. However, their ability to differentiate between gluteus medius tendinosis or a partial-thickness tear may be limited. Clear, concise, and consistent guidelines for the identification of specific structural pathologies are needed. As GTPS is a clinical syndrome, any findings observed on imaging should be placed within the context of thorough clinical examination, with a focus on the clinical features and functional limitations to accurately diagnosis and direct treatment (Docking et al., 2015; Cook et al., 2016).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2019.01.011.

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