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Original article

Magnetic resonance imaging versus ultrasound in diagnosis of distal biceps tendon avulsion

Diagnostic des ruptures distales du tendon Biceps brachial : imagerie ou résonance magnétique versus échographie

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ABSTRACT

Introduction: The severity of distal biceps tendon (DBT) injuries ranges from partial to complete tears leading to various clinical manifestation. Accuracy of early diagnosis and selection of treatment are critical to long-term recovery outcomes. Magnetic resonance imaging (MRI) or ultrasonography (US) are two commonly modalities for pre-operative diagnosis. The objective of this study was to determine the efficiency of MRI and ultrasonography US in the diagnosis of DBT rupture confirmed by operative findings.
Hypothesis: MRI and US are equally effective in terms of accuracy, sensitivity and specificity.
Material and methods: A total of 31 patients with DBT avulsion and surgical treatment were recruited for this retrospective study. All these patients received both US and MRI examinations prior to surgery. DBT avulsion was classified into partial tear and complete tear. Diagnosis outcomes by MRI and US were analyzed and compared statistically for the accuracy, sensitivity, and specificity in discriminating partial and complete DBT tears.
Results: The accuracy of MRI and US was 86.4% and 45.5% in diagnosis of complete DBT rupture, respectively. Accuracy rate of MRI (66.7%) was the same as US in diagnosis of partial tear. Overall accuracy rate of MRI (80.6%) was higher than US (51.6%) in diagnosis all DBT avulsion with an odds ratio of 3.9. Sensitivity and specificity of MRI were 76.0% and 50.0%, while that of ultrasonography were 62.5% and 20.0%.
Conclusions: The findings of this study suggest that MRI is a more accurate imaging modality at correctly identifying the type of DBT tear although US is more cost-effective.
Level of evidence: III, Cohort study, Diagnosis study.

1. Introduction

Rupture of the distal biceps tendon (DBT) typically occurs in middle-aged (40–60 years old) males who sustain an eccentric load to the biceps muscle belly [1]. The incidence of the distal biceps tendon rupture is estimated to be a rate of 2.55/100,000 patient-years [2].

The distal biceps tendon is distally attached to radial tuberosity and to the fascia on the medial side of the forearm by bicipital aponeurosis [3]. This fibrous tissue originates from the myotendinous junction of the biceps muscle and runs medially to merge with the antebrachial fascia [4]. Peritendinous fluid can surround the tendon in acute traumatic injuries [5,6].

The DBT injuries ranging from partial to complete tears yield various clinical manifestations, which can make diagnosis difficult and hence affect therapeutic decision-making. Partial tears are defined as the tears that damage the soft tissue but are not completely detached from the radial tuberosity. A complete tear is defined as a tear that detaches the tendon completely from its attachment point at the bone. Complete tears require surgical repair, while it is controversial if partial tear can be treated conservatively. Complete DBT ruptures most frequently occur with tendon detachment from the bicipital tuberosity, while partial tears can spread over the tendon and myotendinous junction [7]. Accurate diagnosis is critical for the selection of treatments.

Patients of complete DBT rupture typically present with ecchymosis, pain in antecubital fossa, bruising over the distal arm,

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decreased strength of supination and flexion, deformity of muscle contour such as a visible and palpable defect of the tendon [8–10]. The classic signs and symptoms varies among complete distal biceps tendon rupture patients [11–15]. Patients presenting with partial tears or complete tears may also have only subtle difference in clinical manifestations [16]. This can lead to difficulty in differential diagnosis and therapeutic decision-making. Partial distal biceps tears may present with insidious onset with a diagnosis of chronic degenerative tendinosis [3]. Hence, in addition to physical examination, advanced imaging modalities such as ultrasonography or magnetic resonance imaging (MRI) are required to confirmed the diagnosis [4].

While clinical examination may be sufficient to diagnose a complete rupture [17], imaging is usually utilized to confirm the diagnosis and determine the degree of tendon retraction, especially when history and physical examination alone are insufficient with an uncertain diagnosis. Both magnetic resonance imaging (MRI) and ultrasound scanning (US) have been advocated as imaging modalities to assess the integrity of the distal biceps tendon [18–20]. MRI has been reported to be reliable in identifying distal bicep tears with a 100% sensitivity and 82.8% specificity for diagnosis of CT and PT, respectively [16]. MRI is considered the gold standard in the diagnosis of DBT injuries, however, it is cost-expensive, and hence it is ordered only when there is a doubt for a rupture where the ultrasound was not very precise.

The use of ultrasonography as an imaging test for diagnosing DBT injuries is becoming increasingly common. In the past, it had been considered to have less diagnostic value than MRI, mainly because of its lack of accuracy in assessing injuries at the attachment site [21]. Modern improvements in US resolution allow it to have attractive advantages over MRI including cost-effectiveness, easy access, and ability to perform a dynamic assessment of musculoskeletal anatomy [12]. US are now frequently utilized in the clinic setting by physicians who are not extensively trained on ultrasound maneuvers. There is concern for possible false negative readings that can lead to delayed treatment. The high-resolution and dynamic capability of US make it an excellent tool for examining superficial structures around the elbow [22] and has been reported to have 95% sensitivity, 71% specificity and 91% accuracy in the diagnosis of complete versus partial DBT tears using their methods [23].

The purpose of our study was to compare the diagnostic efficiency of MRI versus US using commonly used criterion for patients who had both imaging modalities performed prior to surgery. These patients were treated by DBT repair surgery, hence severity of DBT tears were identified based on surgical field gross findings and reasons for lower diagnosis sensitivity and specificity could thus be found out. Our hypothesis was that MRI and US would be equally effective in terms of accuracy, sensitivity and specificity.

2. Material and methods

Thirty one patients with distal biceps rupture treated by surgery were included in the retrospective study. All procedures for this retrospective study were approved by our Institutional Review Board for this retrospective clinical study. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). Informed consent was obtained from all patients for being included in the study.

All patients underwent proper clinical examinations including pre-operatively standardized ultrasound scanning and MRI and then treated by surgery. Physical examination included the assessment of pain at the antecubital region, questionnaire for elbow weakness and functionality assessment, palpation of the anterior brachial region for a bunching up of the muscle and a palpable defect. Clinical diagnosis for complete tear was basically made when a bunching up of the muscle and a palpable defect of the DBT. The complete DBT tears were treated with tendon debridement and re-attachment of the biceps tendon to its native insertion on the tuberosity of the radius using suture anchors or button, partial tears were treated with completion of tear, tendon debridement, and subsequent re-attachment of tendon to bone.

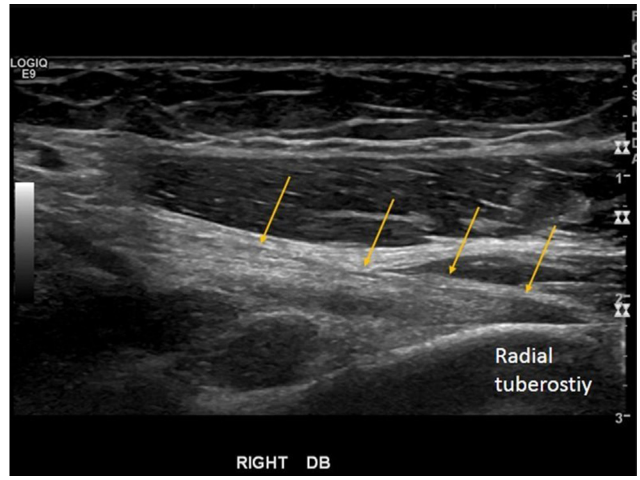

Fig. 1. A normal small amount of anisotropy (dark area, arrows) at the distal insertion.

Standardized ultrasound scanning examination (ultrasonography) was performed by an experienced ultrasonographer, under the supervision of a musculoskeletal fellowship trained radiologist, using an ultrasonic machine (GE Logiq E9, GE Healthcare) and a multi-frequency linear transducer (7–14 MHz). An Anterior approach was used during ultrasound scanning, patient sat on a stool in front of an examination table resting the elbow in full extension and forearm in full supination. The ultrasound transducer was placed in the axial plane on the anterior half of the upper arm and then shifted distally as far as the proximal third of the forearm.

Long axis and Cobra view anterior approach was used for the regions corresponding to the normal anatomy of the DBT evaluation. The distal insertion of the tendon should be viewed. Then the tautness of the rest of the tendon was checked by performing dynamic supination/pronation to make sure that it moves with the radius (Figs. 1 and 2).

Ultrasound findings of following one or multiple signals were considered for DBT injury:

- distal tendon sonographic morphological alterations, including thickening, thinning, discontinuity and morphometry;
- distal tendon sonographic structural alterations, including hyperechogenicity, hypoechogenicity and intratendinous defects along the tendon;
- liquid effusion around the DBT;
- refraction artefact deep to the tendinous stump;
- abnormal fiber stretch and tendon movement or absence of the fiber stretch during dynamic manoeuvres [6,24] (Figs. 3 and 4).

MRI (Figs. 5–7) was performed without contrast and with magnet strength of 3 T MR Imaging System (Ingenia 3.0 T, Philips) with a maximum gradient strength of 30 mT/m, a slew rate of 100 mT/m/ms. Patients were examined in a supine position with the arm resting along the body with a dedicated extremity coil. All scans included T1, T2, and a fluid-sensitive sequence in the axial,

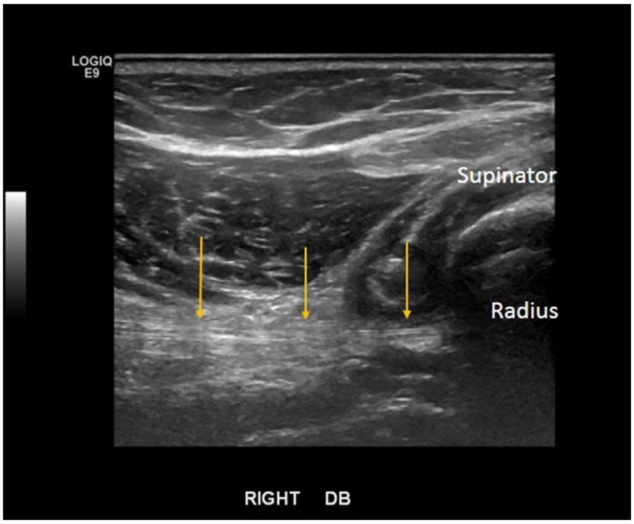

Fig. 2. The tautness of the rest of the tendon by doing dynamic supination/pronation to make sure that it moves with the radius and the fibrillary echotexture of the DBT is observed (arrows).

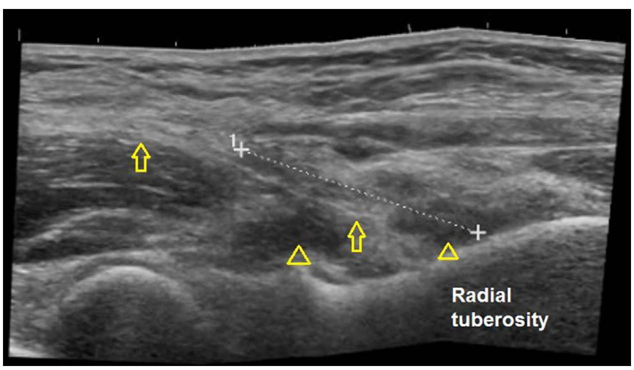

Fig. 3. The long axis view of US with a diagnosis of DBT partial tear. Only a few of the fibrillary echotexture (arrows) of the DBT are observed. Arrowheads show a hyperechogenic gap that corresponds to the torn tendon interface. Dot line shows the defect of DBT including hypoechogenicity (arrowhead) demonstrating the intratendinous defects along the tendon.

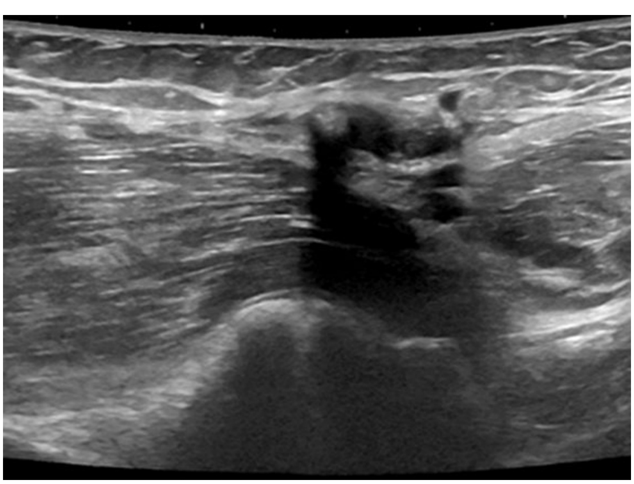

Fig. 4. The long axis view of US with a diagnosis of DBT complete tear.

sagittal, and coronal planes. All MRI images included the area from proximal to biceps musculotendinous junction to distal to radial tuberosity (Fig. 5). All Images of MRIs and US's were read by fellowship trained musculoskeletal radiologists.

Fig. 5. An MRI of intact brachial biceps distal tendon inserting on the proximal portion of the bicipital tuberosity (arrow).

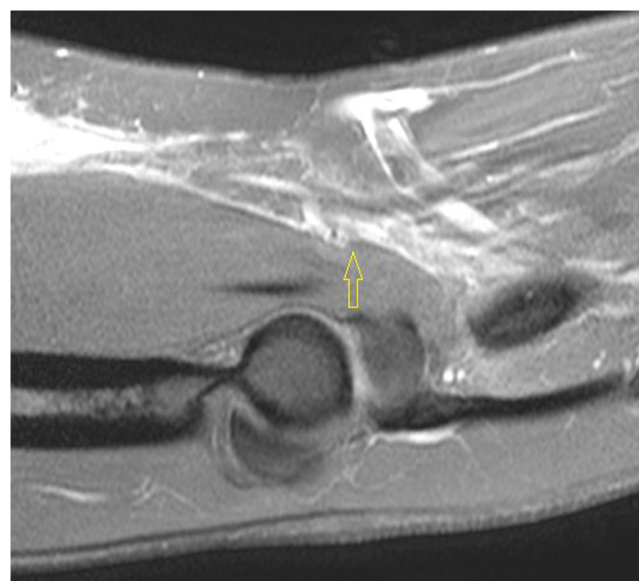

Fig. 6. Unenhanced MR imaging axial slice shows a partial tear of DBT. The presence of increased signal intensity is found within the tendon indicative of defect and discontinued contour of biceps tendon (arrows).

MRI findings of following one or multiple signals were considered for DBT injury: tendon discontinuity, increased intratendinous signal intensity, peri-tendinous or intra-sheath fluid signal, increased signal intensity of biceps muscle, increased signal intensity in surrounding soft tissue, and edema in radial tuberosity [16], (Figs. 6 and 7).

Diagnosis criteria: The diagnosis of the radiographic interpretations and operative findings were categorized as the following categories: partial tear and complete tear. Complete tear was defined as complete loss of DBT attachment to the radial tuberosity, partial tear was defined as tendon disruption with partial DBT attached to the radial tuberosity and tears spread over myotendinous junction or tendon itself.

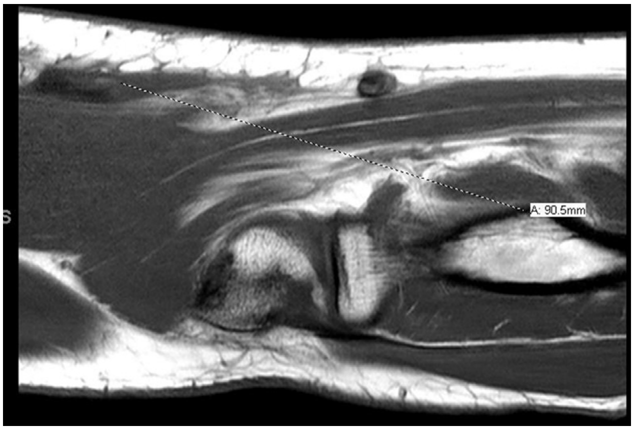

Fig. 7. T1 sagittal MRI slice of DBT patient with a MRI diagnosis of a complete tear with tendon retraction.

Table 1
Accuracy of MRI and US in Diagnosis of Different DBBT Injury.

Methods	Correct Diagnosis		Total
	Yes	No	
Complete Tear			
MRI			
Count	19	3	22
Accuracy Rate	86.40%	13.60%	100.00%
Ultrasound			
Count	10	12	22
Accuracy Rate	45.50%	54.50%	100.00%
Partial Tear			
MRI			
Count	6	3	9
Accuracy Rate	66.70%	33.30%	100.00%
Ultrasound			
Count	6	3	9
Accuracy Rate	66.70%	33.30%	100.00%

Statistical analysis was performed to determine the accuracy, sensitivity, and specificity, odds ratios, and risk ratios of MRI and ultrasonography using SPSS software (IBM, version 25). For each statistical value, the 95% confidence interval (95%CI) was calculated based on a normal distribution. Chi Square (x^2) (Pearson–test) was used to calculate the difference between qualitative variables. *P*-value smaller than 0.05 was considered as a statistical significant level.

3. Results

At the time of surgical repair, all patients were found to have either a complete tear or partial tear of the distal biceps tendon. In two partial tear patients, the fascia appeared to be intact, however, palpation over the tendon, a deficient gap of tendon was identified. Of the 31 patients who had both MRI and US preoperatively with operative notes available for review, 22 were confirmed to have complete tear and 9 have partial tear. All patients with PT subsequently underwent completion of the tear followed by distal-biceps repair.

The results for the individual patients are shown in tables. Table 1 shows the outcomes of using MRI and US in diagnosis of complete tear. Among 22 complete tear patients, MRI diagnosed 19 patients correctly, 3 other patients were diagnosed as partial tear injury, and the accuracy rate was 86.4%. Accuracy rate of MRI was significantly higher than US which only had 45.5% in complete tear diagnosis (Chi^2, Pearson–test, $p = 0.004$). Odds Ratio of MRI versus US in diagnosis of complete DBT tear was 7.6 (Table 2).

Table 2
Odds Ratio and Ratio Risk of MRI and US in Diagnosis of DBBT Injury.

OR/RR	Value	95% Confidence Interval	
		Lower	Upper
Complete Tear			
Odds ratio for methods (MRI/Ultrasonic)	7.6	1.73	33.34
Ratio risk of correct diagnosis of complete tear	1.9	1.16	3.09
Ratio risk of misdiagnosis of complete tear	0.25	0.08	0.76
Partial Tear			
Odds ratio for methods (MRI/Ultrasonic)	3.9	1.25	12.16
Ratio risk of correct diagnosis of complete tear	1.56	1.06	2.28
Ratio risk of misdiagnosis of complete tear	0.4	0.17	0.89

Table 3
Accuracy of MRI and US in Diagnosis of Overall DBBT Injury.

Methods	Correct Diagnosis		Total
	Yes	No	
MRI			
Count	25	6	31
Accuracy Rate	80.6%	19.4%	100.0%
Ultrasonic			
Count	16	15	31
Accuracy Rate	51.6%	48.4%	100.0%

The outcomes of using MRI and US in diagnosis of partial DBT tear (Table 1). Among 9 partial tear patients, MRI diagnosed 6 patients correctly, 3 other patients were diagnosed as complete tear injury, and the accuracy rate was 66.7%. Accuracy rate of MRI was the same as US in diagnosis of partial tear (Chi^2, Pearson–test, $p = 1.000$). Odds Ratio of MRI versus US in diagnosis of partial DBT tear was 1.0 (Table 2).

Table 3 shows the outcomes of comparing MRI and US in diagnosis of all DBT tears. Among all 31 patients in this study, MRI diagnosed 25 patients (80.6%) correctly, while US diagnosed 16 of 31 (51.6%) patients correctly. Accuracy rate of MRI was the same as US in diagnosis of DBT tear (Chi^2, Pearson–test, $p = 0.016$). Odds Ratio of MRI versus US in diagnosis of complete DBT tear was 3.9 (Table 3).

For discriminating complete tear from partial tear, sensitivity and specificity of MRI were 76.0% and 50.0%, while sensitivity and specificity of ultrasonography were 62.5% and 20.0%, respectively.

4. Discussion

Our results suggest that MRI is a more accurate imaging modality at correctly identifying the underlying status of the distal biceps tendon. In our study, MRI correctly identified the status of the distal biceps tendon 80.6% of the time in comparison to 51.6% of the time seen in US. It was reported that MRI was 100% sensitive and 82.8% specific for detecting complete distal bicep ruptures [16], our sensitivity and specificity appeared to be lower but also showing that MRI accuracy was better than US. Our results showed a same trend favoring MRI as it demonstrated better sensitivity, specificity, and accuracy than US for detecting a complete tear. In our study, sensitivity, specificity, and accuracy for detecting partial tear were not different between MRI and US. The ability of both MRI and US can attain high resolution of superficial structures [12], but cannot ascertain the status of unstructured tears, this may explain the tendency in the findings of partial tear of DBT.

Modern improvements in US resolution have made this imaging modality one of particular interest for diagnosing the status of the distal biceps tendon. Sonographic features of complete ruptures demonstrate absence of tendon at the radial tuberosity, a mass in the antecubital fossa and fluid in the tendon gap. PTs, on the other hand, demonstrate intra-tendinous hypo-echogenicity with evidence of tendon thinning [18]. US was reported to have 95% sensitivity, 71% specificity and 91% accuracy at the diagnosis of complete distal biceps tendon ruptures [5], these results differ from those seen in our study. Such differences can be explained by the imaging pitfalls of US as it relates to evaluation of deep anatomic structures [5], the reliance on good operator experience [12], and musculoskeletal radiologists attuned to the imaging modality. The fact that there were 9 patients in our study with US readings of PTs and MRI along with operative findings of CTs lends support to the potential limitation of US as it relates to its ability to assess deep anatomic structures.

It is well known today the difference in ultrasound results between a not specialized radiologist and a radiologist specialized in musculoskeletal ultrasound. In addition, a recent study shows a sensitivity of the ultrasound examination of 91% when performed by a radiologist-specialist and 40% when performed by no-specialists [25]. This may explain the reason why the accuracy of US diagnostic outcomes was low.

Operative treatment is generally recommended for patients presenting with history and physical of a DBT rupture when either US or MRI demonstrating CT or PT with greater than 50% involvement of the tendon. In such an instance the status of CT versus PT remains a moot point as both are treated in a similar fashion. However, an equally important counter-argument can be made for correctly identifying PTs that involve < 50% of the tendon. Such patients at initial presentation may be better-suited candidates for initial non-operative intervention and incorrectly diagnosing these patients based on radiographic readings would put the patient under the unnecessary risks and complications of surgical intervention. Such is the case where diagnostic imaging may play a critical role for patients presenting with signs and symptoms of a DBT rupture.

To date, the literature that look at the accuracy, sensitivity or specificity of either US or MRI alone for DBT rupture diagnosis are still few in number. Although sensitivity and specificity in our report is not better than what have been reported by others, our research outcome can still contribute to future meta-analysis for more accurate profile of DBT injury pre-operative diagnosis using MRI and US.

MRI is a useful imaging modality for patients presenting with an equivocal history and physical examination as it is more likely to correctly discern between a CT and PT, which ultimately impacts the decision of operative versus non-operative intervention.

There are several limitations to our study. First, the retrospective nature of the study consists of inherent selection bias. Surgeons would most likely have ordered both modalities because of questionable diagnosis using a single modality. Second, our analysis was based on the interpretations of several different radiologists without any ability to ascertain intra-observer and inter-observer reliability. Additionally, it would have been ideal for the PTs to be quantified as a percentage of tendon tear, which could help guide decision making for operative versus non-operative intervention. Our study also fails to capture those patients who may have had a diagnosis of PT on MRI or US and were successfully treated non-operatively as we only looked at patients who were operated on.

Future research will be a prospective study to recruit the patients having a distal biceps tendon tear with both MRI and US diagnosis. We will quantify the severity of avulsion based on the percentage of tear of the whole tendon and determine the sensitivity and specificity of both MRI and US diagnosis. Inter-observer and intra-observer variances for the radiographic readings will be investigated. Multiple center studies may be conducted to understand disparities of diagnostic accuracy among different health systems.

5. Conclusions

MRI appears to be a more accurate imaging modality over US as it pertains to correctly diagnosing the underlying status of the distal biceps tendon avulsion. Although the results were contraindicative to our hypothesis, it reflected a natural consequence under current standard of procedures in our health system. MRI is a useful imaging modality for patients presenting with an equivocal history and physical examination as it is more likely to correctly differentiate a CT from PT.

Disclosure of interest

Dr. Stephanie Muh serves as consultant for Exactech and Depuy Mitek.

The other authors declare that they have no competing interest.

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Contributions of each author

J. Lynch, C. Yu, C. Chen, and S. Muh all contribute to manuscript writing.

S. Muh performed the surgical procedures and coordinated the study.

J. Lynch and C. Yu assisted in surgery and collected clinical data.

C. Chen did statistical analysis and reviewed the article.

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