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The effectiveness of combined CT arthrography and sub-acromial bursography as a novel modified technique in characterization of rotator cuff tears

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Abstract

Background: CT arthrography is an alternative technique to MRA in shoulder imaging, including RCTs; however, CTA alone could not stage RCTs and suffers from some limitations. Being the only technique that could highlight the rotator cuff tendons from both surfaces, our study was aimed to assess the use of multi-detector CTA with concurrent sub-acromial bursography as a new technique in detection and characterization of rotator cuff tears.

Results: Different types of RCTs were characterized including bursal surface tears. Different grades of RCT size were classified. There was 100% sensitivity of CTA concerning detection of all rotator cuff tendons however with variable specificity that was very high in supraspinatus tendon.

Conclusions: CTA when combined with sub-acromial bursography is a reliable tool could be used in preoperative planning in RCTs, this combination modifies the CTA technique, allows for detailed characterization of type and size of RCTs, and for detection of bursal surface tears.

Background

Rotator cuff tear (RCT) is a common problem occurring in middle- and old-aged people; it is a leading cause to shoulder dysfunction. The grade of tear and the integrity of the entire tendon are important factors that influence RCT management. Poor quality tendon can compromise usual arthroscopic rotator cuff fixation and may require specialized techniques [1].

Multi-detector CT arthrography (CTA) is an alternative technique to MR arthrography (MRA) in shoulder imaging, including certain rotator cuff injuries that require MRA to be fully characterized. CTA has been proven to have high diagnostic performance similar to MRA for evaluation of full-thickness RCTs, however; CTA alone is insensitive to bursal sided partial-thickness and could not detect pure intra-substance tears. Moreover, although CTA alone can detect the partial-thickness articular surface tear, it could not grade it except when additional full-thickness tear is present anywhere on the cuff allowing for concurrent sub-acromial bursography, thus in order to accurately categorize partial-thickness RCTs on CTA, the affected tendon should be highlighted by contrast material on both articular and bursal surfaces. CTA has the ability to adequately asses and clarifies RCT owing to its inherent high spatial resolution that depends on the attenuation difference between the articular contrast medium and the rotator cuff tendons [2–4].

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Aim of the work

Being the only technique that could highlight the rotator cuff tendons from both surfaces, our study was aimed to assess the use of combined multi-detector CTA with concurrent sub-acromial bursography as a new technique in detection and characterization of rotator cuff tears.

Patients and methods

Study participants

The current study was conducted from April 2018 through November 2018. After it was ethically approved by our institution committee, 30 patients, clinically and sonographically suspected to have rotator cuff tear, were referred from orthopedic and rheumatology clinics, Minia University Hospital, for CT arthrography and bursography using 16-detector CT scanners (Bright-Speed 16; GE Healthcare-America: Milwaukee, USA) and Philips 16-detector row CT machine. Informed written consent was obtained prior to participation in the study from all patients.

Inclusion criteria

Clinically, inclusion criteria for patients were based on the presence of three out of four of the following symptoms: (1) pain at rest or at night, especially when lying on the affected shoulder; (2) pain with lifting and lowering the arm; (3) weakness when rotating the arm; and (4) crackling sensation during shoulder movement. In addition, all patients have suspicious ultrasonographic features suggesting the presence of rotator cuff pathology.

Exclusion criteria

Patients having soft tissue infection about the shoulder were excluded from the study.

Study techniques

Targeted ultrasonographic guided contrast injection

The contrast injection was done using ultrasonographic guidance; the used ultrasonographic machine was Xario-200 Toshiba with multi-frequency 12-MHz linear array transducer. The utilized contrast medium was non-ionic iodinated contrast medium (Iohexol; Omnipaque® 300); it was diluted 1:1 with lidocaine HCL 1%. Two 20-cc syringes were prepared; one for gleno-humeral (GH) joint injection containing 20 cc of prepared contrast, and the other for sub-acromial sub-deltoid (SA-SD) bursal injection containing 15 cc of prepared contrast. The utilized needles were 20-gauge spinal needle for GH injection and 22-gauge 2-inch needle for SA-SD bursal injection. The patient was placed in a lateral or semi-prone position as appropriate with the affected shoulder up. The contrast injection was done with real-time sonographic guidance.

For GH joint injection, the ultrasound transducer (linear 12-MHz or curved 5-MHz as appropriate) was placed in the transverse oblique plane on the posterior lateral shoulder, inferior and parallel to the scapular spine then toggled upwards till visualization of the humeral head on the glenoid. The entry point was just lateral to the transducer. Using the no-touch sterilized technique, the needle was introduced in the same plane of the transducer and angled slightly medially towards the GH interval under direct sonographic visualization of the entire needle length, when the needle tip was visualized within the joint in-between the humeral head and glenoid, injection of the contrast was done until firm resistance occurs (Fig. 1b).

For SA-SD bursal injection, the linear 12-MHz transducer was placed on the top of the shoulder over the lateral border of the acromion and the distal end of the supraspinatus tendon. The entry point was lateral and caudal to the transducer. Using sterilized no-touch technique, the needle was directed medially and transversely in the same plane of the transducer towards the hyperechoic sub-acromial fat plane, and when it was visualized just superficial to the supraspinatus tendon, injection of the contrast was done (Fig. 1a). The bursal injection was canceled in case of full-thickness RCT that allowed for bursal fluid distension during GH joint injection.

Aspiration of joint effusion or bursal fluid was done under direct sonographic visualization and careful sterile technique prior to contrast injection.

CT arthrography

The patient was scanned in "supine" position and palm up; the scan extends from the acromio-calvicular joint above to the bottom of the scapula below, the FOV was wide (about 160 mm) covering the upper humerus and the entire scapula. High-resolution bone algorithm was used, with thin beam collimation (0.625 mm); exposure parameters were 120 kV and 200 mAs.

Image processing and analysis

Standard coronal oblique reformatted images were obtained along the plane perpendicular to the glenoid, whereas sagittal oblique reformatted images were obtained parallel to the glenoid.

Overview of the entire shoulder joint was done through the axial plane. Supraspinatus tendon was assessed on coronal and sagittal planes; subscapularis and infraspinatus tendons were assessed on axial and sagittal planes. Tendon tear was diagnosed when the contrast medium enters within the substance of the tendon from any surface or when focal tendon thinning is detected. Tendon tear was classified according to the direction of contrast passage into simple tear and complex or multi-directional (complex tear was defined as a tear that has more than two directions). Measurement of tear thickness and adjacent normal tendon thickness was done in order to obtain the percentage of tendon affection. Medial extension of the supraspinatus and infraspinatus tendon tears was classified into distal, intermediate, or medial, as follows: distal when the tear is limited by the upper edge of the anatomical neck of

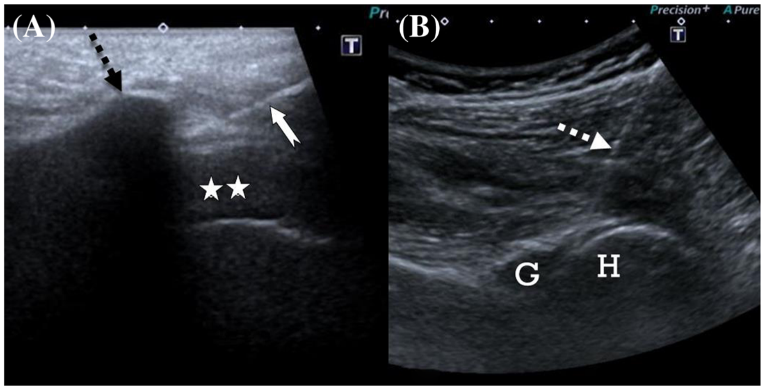

Fig. 1 **a** Coronal sonographic image through the distal acromion (dashed arrow) shows the inserted needle (white arrow) and its tip within the sub-acromial space. Note the distal supraspinatus tendon (stars). **b** Axial sonographic image through the gleno-humeral joint showing the needle track (arrow) with its tip within the gleno-humeral interval. G, glenoid; H, humeral head

the humerus, medial when the tear extends beyond the lower edge of the anatomical neck, and intermediate when the tear is located between the two extremes.

The images were read independently by two radiologists; both have nine years' experience in musculoskeletal imaging. Inter-rater reliability was obtained.

Statistical analysis

Results of combined CTA and bursography were recorded, tabulated, and statistically analyzed using SPSS-16; the data were represented as number and percent. Sensitivity, specificity, and accuracy of CTA were obtained in patients who underwent arthroscopic/operative intervention in comparison to surgical notes.

Results

There were seven males and 23 females. The mean age of male patients was 52 + 8.68 years (range 39–63 years), whereas the mean age of female patients was 51.83 + 11.87 years (range 37–76 years).

MDCT arthrographic findings

There were twelve cases had supraspinatus full-thickness tendon tear, and four cases had subscapularis full-thickness tendon tear (all of which had concurrent supraspinatus tendon tear), and there was no infraspinatus full-thickness tear in the current study.

The partial-thickness RCTs were classified into articular surface tear, bursal surface tear, and interstitial tear; the last one was detected as an extension adjacent tendon tear (from its interstitial component) with no violation of either bursal or articular surfaces (Table 1).

Most rotator cuff tears in the study were complex rather than simple ones; complex tear was defined as a tear that has multiple directions (more than two directions) (Table 2).

Regarding RCT size based on the percentage of thickness affected in each rotator cuff tendon, the partial-thickness tear was graded into four grades; their frequency distribution is expressed in Table 3.

Regarding medio-lateral tear extension, the most frequently encountered location of supraspinatus tear was the intermediate location, then the distal one, whereas in cases demonstrating infraspinatus tendon tears, the most frequent location was the medial location then the intermediate one (Table 4) (Figs. 2, 3, 4, 5 and 6).

There were 24 out of 30 cases underwent arthroscopic repair of RCT, 12 of them had full-thickness supraspinatus tendon tear whereas 12 had extensive partial-thickness supraspinatus tendon tear more than 75% thickness affection. There were high true positive rates in the

Table 1 Types of rotator cuff tear depending on the violated surface

Tear type	SS *n* = 30 *N* (%)	IF *n* = 27 *N* (%)	SSC *n* = 16 *N* (%)
Bursal surface	3 (10%)*	0 (0%)	0 (0%)
Articular surface	16 (53.3%)*	22 (73.3%)	12 (40%)
Full-thickness	12 (40%)	0 (0%)	4 (13.3%)
Interstitial extension from adjacent tendon tear (no violation of either bursal or articular surfaces)	0 (0%)	5 (16.6%)	0 (0%)

*There was one patient had combined bursal and articular surface tears with no communications with each other (Fig. 6)

Table 2 Types of rotator cuff tear depending on tear direction

Type	SS *n* = 30 *N* (%)	IF *n* = 27 *N* (%)	SSC *n* = 16 *N* (%)
Simple	14 (46.6%)	5 (16.6%)	6 (20%)
Complex (multidirectional)	16 (53.3%)	22 (73.3%)	10 (33.3%)

detection of RCTs especially in supraspinatus and subscapularis tendons. There were no false negative cases (Table 5). The other six cases were treated conservatively and their diagnosis was made depending on ultrasonographic and CT arthrographic findings.

Regarding arthroscopically treated cases (24 cases), the CTA demonstrated 100% sensitivity for detection of rotator cuff tendons, with however variable specificity, positive predictive value, and overall accuracy, such results could not be obtained from the other six cases due to lack of reference standard method (Table 6).

There were some minor complications happened post-arthrography, 14 patients had extra-articular contrast extension, and ten of them happened at sites rather than the injection path with lack of increased pressure needed for injection, whereas four patients showed extra-articular extension posteriorly at the injection site but did not affect the diagnostic yield of CTA. No major complication was encountered (Table 7).

Inter-rater reliability

The percent agreement in the study was high; it was 100% for determination of RCT type (either those based on violated surface or direction based type), 100% for tear size-based medio-lateral extension, and 91% for percentage tendon affection in of partial-thickness RCT

Discussion

Although the best imaging tool for rotator cuff partial-thickness tear is MRA, CTA could provide a comparable diagnostic performance particularly in articular surface partial-thickness tear; CTA is an alternative tool when MRA could not be performed for any reason, the inherent high resolution of CTA and high image contrast allows for detection of small tendinous tear. However, CTA alone without subacromial bursography could not characterize the extent of the tear regarding its percentage of fiber affection, in relation to the entire tendon thickness, which could be a significant imaging finding that affect further management. Furthermore, CTA only without subacromial bursography could not detect bursal surface tear; hence, the current study chose the utilization of combined intra-articular and intra-bursal contrast injection to enhance the diagnostic performance of CTA of the shoulder not only in detection but also in characterization of rotator cuff tears [4, 5].

Table 3 Frequency distribution of RCTs depending on the percentage of thickness affection

Range	SS *n* = 30 *F* (%)	IF *n* = 30 *F* (%)	SSC *n* = 30 *F* (%)
0	0 (0%)	3 (10%)	14 (46.6%)
1–25	0 (0%)	2 (6.6%)	0 (0%)
26–50	6 (20%)	8 (26.6%)	3 (10%)
51–75	0 (0%)	12 (40%)	3 (10%)
76–99	12 (40%)	5 (16.6%)	6 (20%)
100	12 (40%)	0 (0%)	4 (13.3%)

Table 4 Medio-lateral extension of RCTs

Tear extension		Number	Percent
Supraspinatus	Distal	3	10
	Intermediate	26	87
	Medial	1	3
Infraspinatus	Distal	2	6
	Intermediate	11	37
	Medial	14	47

The current study characterized both type and size of RCTs. Regarding detection of various types of rotator cuff tear, combined CTA and bursography in the study were able to detect all types of tear based on violated surface; this included pure bursal surface tear which could not be detected if CTA was performed alone. Fermand et al. and Faure et al. [6, 7] studied subacromial CT bursography in patients with a partial surface tear of the rotator cuff tendon. They reported that bursography was able to detect bursal surface irregularities, defect or frank tear; their results were expected as they highlighted the bursal surface of the rotator cuff, so that any superficial surface tear or irregularity would be detected; however, they did not able to assess for tendon thinning or measure accurately the thickness involved by tear, and this would be attributed to diagnostic limitation of CT bursography if performed individually without concurrent CTA [6, 7].

Regarding the direction-based assessment of tear type, the current study was able to differentiate simple tear from multi-directional one; this is aided by the inherent contrast between the low attenuation tendon and the injected intra-articular contrast medium, also the low attenuation of the tendon is generally not affected by the injected contrast, so there are no specific considerations on assessment of tear morphology, this appears to be different from MRA in which contrast medium can be imbibed by the adjacent tendinopathy or frayed friable tendon margins and therefore assessment of tear on T1 fat-suppressed images only could reveal inaccurate

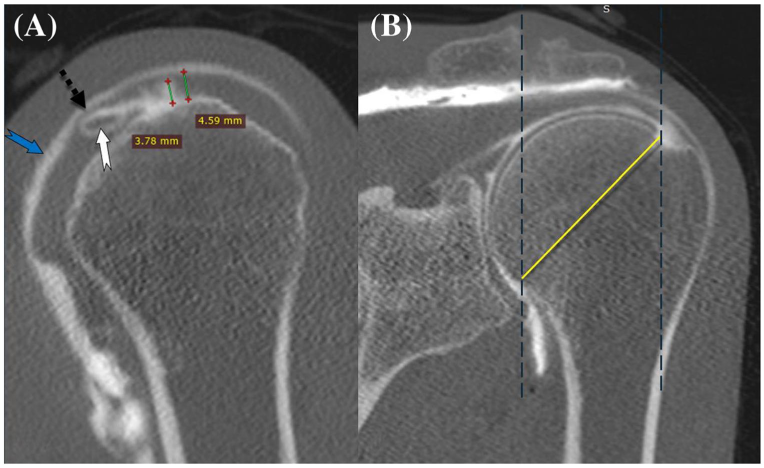

Fig. 2 Sagittal oblique (**a**) and coronal oblique CT arthrographic images (**b**) through the supraspinatus tendon, in a 47 years old male patient complained from left shoulder pain increased on arm lifting, there is a simple partial-thickness articular surface tear of supraspinatus tendon at its footprint affecting 82% of its thickness. Note the potential for percentage affection measurement was got by virtue of contrast highlighting of tendon bursal surface from bursography (blue arrow). Biceps long head tendon (white arrow) is easily depicted within the rotator interval with overlying coraco-humeral ligament (dashed black arrow)

results, and thus T1 fat-suppressed images must be assessed alongside fluid sensitive images [8].

Regarding tear size and its mediolateral extension, the study followed the same way described by Thomazeau et al. [9], who described full-thickness rotator cuff tear on arthroscopy and categorized it, in relation to anatomic neck of the humerus, into distal, intermediate, and retracted (replaced by medial in our study). This easily correlated arthroscopically based method differentiates massive rotator cuff tears form non-massive ones; it could be helpful if become a part of the diagnostic checklist in pre-operative arthrographic reporting, as it provides an insight about the quality of the tendon, and thus plays an important role in planning and tailoring

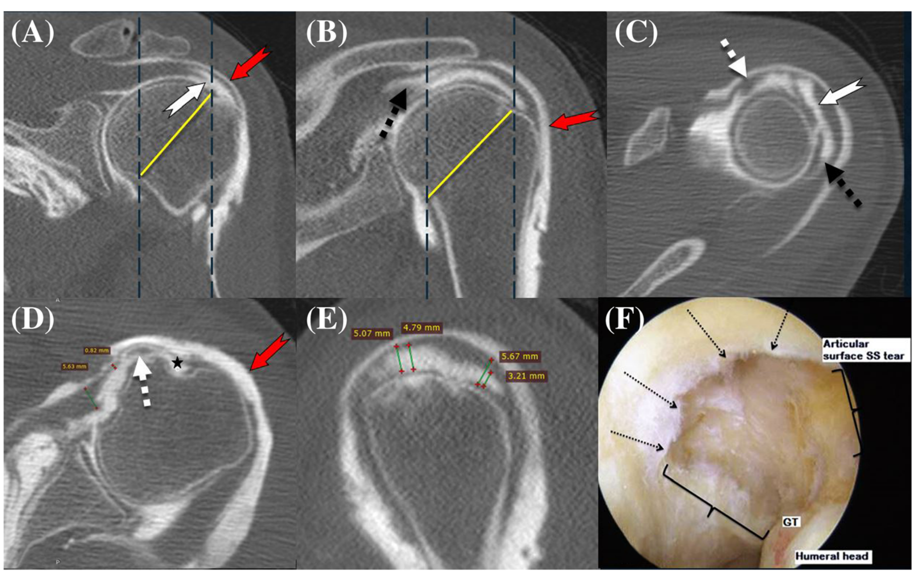

Fig. 3 A 53 years old female patient complained from long-standing left shoulder weakness and pain increased on lifting or rotating her arm. Coronal oblique CT arthrographic images (**a**, **b**) demonstrate intermediate articular surface supraspinatus tendon tear (white arrow) and medial articular surface infraspinatus tendon tear (dashed black arrow). Axial (**c**, **d**) images show complexity and irregularity of both tears; the subscapularis tendon shows extensive partial thickness tear with dislocated biceps lone head tendon (dashed white arrow) and empty biceptal groove (star). Sagittal oblique (**e**) image show how contrast within the SA-SD bursa could highlight the bursal surface of the rotator cuff allowing for accurate measurement of thickness of the tear. Arthroscopic image (**f**) demonstrates large articular surface tear (area between brackets) through the supraspinatus tendon, with irregular edge (arrows)

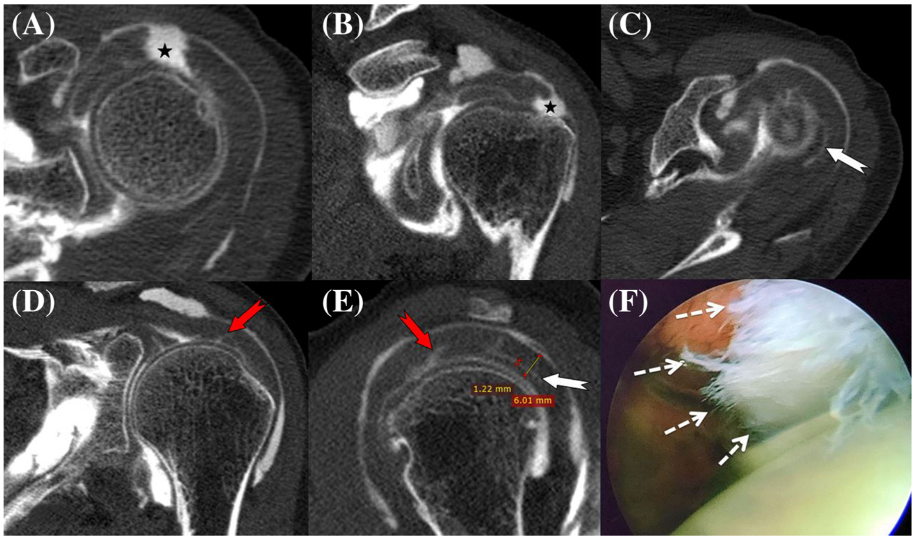

Fig. 4 CTA in 50 years old female patient complained from left shoulder weakness and pain increased on lifting or rotating her arm. Axial (**a**) and coronal oblique (**b**) images show full-thickness supraspinatus tendon tear (star) allow for bursal contrast passage and cancelation of bursal injection. More cephalic axial image (**c**) with more posterior coronal oblique image (**d**) and sagittal oblique CT arthrographic image (**e**) demonstrate interstitial extension into the remaining supraspinatus tendon (red arrow) and thin articular surface infraspinatus tendon tear extending interstitially (white arrow). Arthroscopic image (**f**) shows full-thickness supraspinatus tendon tear with frayed edges (arrows)

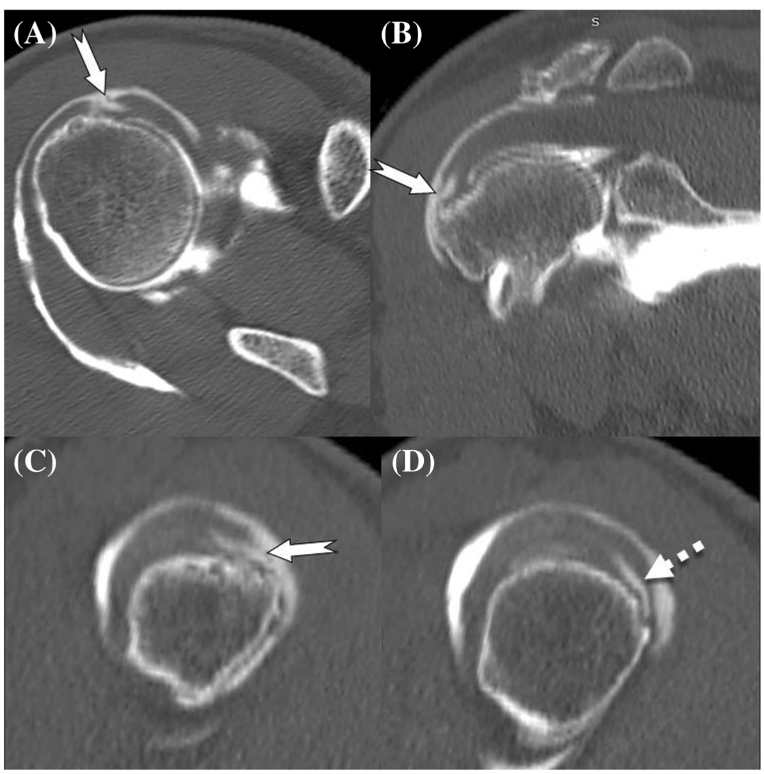

Fig. 5 Axial (**a**), coronal oblique (**b**), and sagittal oblique (**c**, **d**) CT arthrographic images in a 63 years old male complained from right shoulder pain especially on moving or lifting his arm, showing pure bursal surface defect (notched arrow) involving the anterior and distal fibers of the supraspinatus tendon with contrast leakage within its substance (dashed arrow). Note intact articular surface. Note that CTA alone could not be able to detect such a tear

Fig. 6 A 52 years old female patient complained from left shoulder pain with some limitation of movement. Axial (**a**), coronal oblique (**b**), and sagittal oblique images (**c**, **d**) CT arthographic images show double partial thickness tear through the bursal (notched arrow) and articular (dashed arrow) surfaces of the supraspinatus tendon, none of which communicate with the other, excluding the presence of full-thickness defect. Note that CTA alone will miss the bursal surface component

the repair technique as poor quality tendon can compromise usual arthroscopic rotator cuff fixation and may require specialized techniques. Detailed characterization of the RCTs on CTA by means of tendon tear size whether small or massive, presence or absence of interstitial extension within the remaining apparently spared tendon and the degree of affected thickness whether partial- or full-thickness would reduce the failure rate of rotator cuff repair that might occur in marked or massive tears [1, 9].

Regarding the percentage of affected thickness in the current study, most of partial-thickness tears in the study fall in either more than one-half or more than three-fourth thickness affection categories; some tears were so extensive, but still affect < 100% of tendon thickness. Tendon thickness affection is an important factor that should be reported on CTA; distinction between shallow and deep partial-thickness tear is necessary for pre-operative planning, as operative/arthroscopic repair of partial-thickness rotator cuff tear is indicated when more than three fourths of tendon thickness affection. Extensive partial-thickness tears sparing thin fibers (near full-thickness) are repaired by the same fashion as done in full-thickness ones. Charousset et al. [4] studied the accuracy of CTA in rotator cuff tear; they found different sensitivities and specificities for diagnosis of different rotator cuff tendon tears, although they found high sensitivity (99%) and specificity (100%) for diagnosis of supraspinatus tear, they did not characterize such tears, regarding their percentage of fiber affection. Oh et al. [10] assessed the effectiveness of CTA for diagnosis of rotator cuff disorders with arthroscopic correlation; they found high sensitivity (89%) and specificity (98%) in full-thickness tear; however, for partial-thickness rotator cuff tear, the sensitivity was very low (22%) with relatively high specificity (87%), this is could be attributed to poor sensitivity of CTA in bursal surface partial thickness tear. Omoumi et al. [2] studied the multidetector CT

Table 5 Detection of different tendinous tears by combined CTA and bursography compared with arthroscopic findings, such results are about the arthroscopically treated cases only (24 cases), and this is not applicable for the rest of cases (6 cases)

Tendon	True positive	False positive	True negative	False negative
Supraspinatus	24	0	0	0
Infraspinatus	19	3	2	0
Subscapularis	12	2	10	0

Table 6 Sensitivity, specificity, positive predictive value and accuracy of combined CTA and subacromial bursography in the detection of RCTs

Tendon	Sensitivity (%)	Specificity (%)	PPV (%)	Accuracy (%)
Supraspinatus	100	100	100	100
Infraspinatus	100	40	86.3	87.5
Subscapularis	100	83	85.7	91.6

arthrography in evaluation of rotator cuff tears and compared them with 1.5-T MRA, although they found similar diagnostic performance of both techniques, CTA had lower sensitivity in partial-thickness supraspinatus tendon tears (60%). The distinction between different grades of thickness affection in partial thickness tear is allowed only when concurrent bursography is performed with CTA. To the best of the authors' knowledge, all known studies that assessed the value of CTA in RCTs assessed its value in detection of RCTs, not in their characterization, they were not able to assess the percentage of tendon thickness affection, and this is the first article trying to study and highlight such a point, that would refine the CT arthrographic study when performed in the context of rotator cuff tear [2, 4, 10–14].

The sensitivity of CTA and concurrent sub-acromial bursography in detection of rotator cuff tears in arthroscopically treated patients was 100%, whereas the specificity was variable due to false positive results regarding the subscapularis and infraspinatus tendons, it was 100% for supraspinatus tendon tear, 83% for subscapularis tendon tears and 40% for infraspinatus tendon tear. Concerning infraspinatus tendon false positive results in our study; all of which demonstrated interstitial tear type which an was intra-substance extension from adjacent supraspinatus tear that resulted in infraspinatus fiber delamination, this type of tear could not be visible at arthroscopy and this might explain this high false positive rate on CTA and concurrent bursography for this tendon. Regarding the false positive rate in subscapularis tendon, it could be attributed to technical difficulty to asses it at arthroscopy compared with the supraspinatus and infraspinatus tendons [2, 15, 16].

Table 7 Complications of CTA

Complication	*N* (%) *N* = 30
Post-arthrography shoulder pain	6 (20%)
Extra-articular injection at the injection site	4 (13.3%)
Extra-articular extension through the subscapularis recess into the subscapularis muscle	8 (26.6%)
Extra-articular extension through the long head of biceps tendon sheath	2 (6.6%)
Vasovagal attack	3 (10%)
Infection/septic arthritis	0 (0%)

The current study has low complication rates, the percentage of extra-articular contrast injection at the site of needle path was low, and its effect was minimal without image interpretation difficulties; this could be due to injecting the contrast in real-time fashion using ultrasonographic guidance which allowed for accurate needle localization and proper targeted injection. There were some cases demonstrated extra-articular contrast leaks from the subscapular recess into the subscapularis muscle and from the biceps synovium, although there was no increased resistance experienced during contrast injection. Such unexplained findings might be related to associated capsulitis with subsequent weakness of the joint capsule. Ogul et al. [17] studied the extra-articular contrast material leakage within sites unrelated to the injection path in shoulder MRA, they observed three sites of contrast material leakage at subscapular recess, the synovium of the biceps and the axillary recess, they found that the amount of extravasation was significantly higher in patients with adhesive capsulitis compared with patients with different diagnosis, and the most frequently associated shoulder pathology with extravasation was superior labrum anterior-posterior (SLAP) lesion [17].

Study limitation

The study included a relatively small sample of cases

Conclusion

CTA of the shoulder combined with concurrent sub-acromial bursography is a useful cost-effective imaging method could be used reliably in preoperative planning in partial-thickness rotator cuff tears, this combination modifies the CTA technique and allows for detailed characterization of type and size of partial-thickness rotator cuff tear, it also allows for detection of partial-thickness bursal surface tears. Furthermore, CTA has high diagnostic performance in detection of full-thickness rotator cuff tear. Lastly, use of ultrasonographic guidance is a useful tool for accurate targeted contrast injection in CTA and bursography yielding a low rate of post-arthographic complications.

Abbreviations

CTA: Multi-detector CT arthrography; GH: Gleno-humeral; MRA: MR arthrography; RCT: Rotator cuff tear; SA-SD: Sub-acromial sub-deltoid; SLAP: Superior labrum anterior-posterior

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Authors' contributions

MF and AR carried out the injection technique and participated in the study analysis. AN and AH carried out the clinical issues of the cases including the treatment options of study participants. AF participated in the design of the study and performed the statistical analysis. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
This study was approved by the Research Ethics Committee of the Faculty of Medicine at Minia University in Egypt on 10 March 2018; reference Number of approval: FMREC18112. All patients included in this study gave written informed consent to participate in this research.

Consent for publication
All patients included in this research gave written informed consent to publish the data contained within this study.

Competing interests
The authors declare that they have no competing interests.

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References

1. Denard PJ, Burkhart SS (2011) Techniques for managing poor quality tissue and bone during arthroscopic rotator cuff repair. Arthroscopy 27(10):1409–1421
2. Omoumi P, Bafort AC, Dubuc JE, Malghem J, Vande Berg BC, Lecouvet FE (2012) Evaluation of rotator cuff tendon tears: comparison of multidetector CT arthrography and 1.5-T MR arthrography. Radiology. 264:812–822
3. Fritz J, Fishman EK, Small KM, Winalski CS, Horger MS, Corl F, McFarland E, Carrino JA, Fayad LM (2012) MDCT arthrography of the shoulder with datasets of isotropic resolution: indications, technique, and application. AJR 198:635–646
4. Charousset C, Bellaiche L, Duranthon LD et al (2005) Accuracy of CT arthrography in the assessment of tears of the rotator cuff. J Bone Joint Surg Br 87(6):824–828
5. Tuite MJ (2016) Rotator cuff. In: Blankenbaker DG, Davis KW, Sonin A, Crim JR, Tuite MJ, Andrews CL (eds) Diagnostic imaging. Musculoskeletal trauma, 2nd ed. Amirsys. Elsevier. Section 2, Altona, Manitoba, Canada, pp 102–145
6. Fermand M, Blanchard JP, Vergeron H, Goldberg D (1999) Rotator cuff imaging using bursography coupled to helical computed arthrotomography. Rev Rhum Engl Ed 66(3):131–135
7. Faure C, Noel E, Girod S, Streichenberger E, Peyret-Didier S, Bochu M (2001) Value of CT bursography in evaluation of rotator cuff tears. J Radiol 82(1):51–54
8. Steibbach LS (2010) MRI of the rotator cuff. In: Chung CB, Steibbach LS (eds) MRI of the upper extremity: shoulder, elbow, wrist and hand, vol 15, 1st edn. LWW, Philadelphia, pp 239–276
9. Thomazeau H, Gleyze P, Lofosse L, Walch G, Kelbérine F, Coudane H (2000) Arthroscopic assessment of full-thickness rotator cuff tears. Arthroscopy 16(4):367–372
10. Oh JH, Kim JY, Choi JA, Kim WS (2010) Effectiveness of multidetector computed tomography arthrography for the diagnosis of shoulder pathology: comparison with magnetic resonance imaging with arthroscopic correlation. J Shoulder Elbow Surg. 19(1):14–20
11. Matthewson G, Beach CJ, Nelson AA, Woodmass JM, Ono Y, Boorman RS, Lo IK, Thornton GM (2015) Partial thickness rotator cuff tears: current concepts. Adv Orthopedics.:458786 https://doi.org/10.1155/2015/458786
12. Shaffer B, Huttman D (2014) Rotator cuff tears in the throwing athlete. Sports Med Arthrosc Rev. 22(2):101–109
13. Liu JN, Garcia GH, Gowd AK, Cabarcas BC, Charles MD, Romeo AA, Verma NN (2018) Treatment of partial thickness rotator cuff tears in overhead athletes. Curr Rev Musculoskelet Med. 11(1):55–62
14. Lecouvet FE, Simoni P, Koutaïssoff S, Vande Berg BC, Malghem J, Dubuc JE (2008) Multidetector spiral CT arthrography of the shoulder. Clinical applications and limits, with MR arthrography and arthroscopic correlations. Eur J Radiol 68(1):120–136
15. Waldt S, Bruegel M, Mueller D et al (2007) Rotator cuff tears: assessment with MR arthrography in 275 patients with arthroscopic correlation. Eur Radiol 17(2):491–498
16. Chen Y-P, Ho W-P, Chuang T-Y (2015) Arthroscopic management of calcific tendonitis of the subscapularis tendon with subcoracoid stenosis. Journal of Orthopaedic Science 20(5):935–938
17. Ogul H, Bayraktutan U, Ozgokce M, Tuncer K, Yuce I, Yalcin A, Pirimoglu B, Sagsoz E, Kantarci M (2014) Ultrasound-guided shoulder MR arthrography: comparison of rotator interval and posterior approach. Clin Imaging. 38(1):11–17

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