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Scientific Surgery Center named after Academician M. Topchubashov, ¹Central Clinical Hospital, Baku, Azerbaijan**DIAGNOSTIC IMAGING APPROACHES FOR SUBACROMIAL IMPINGEMENT SYNDROME**

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This study presents a structured diagnostic algorithm for subacromial impingement syndrome, incorporating radiography, MRI, and CT imaging, with a focus on diagnostic accuracy and treatment planning. MRI demonstrated high specificity (100 %) and moderate sensitivity (79 %) for subacromial impingement syndrome, with 76 % overall accuracy. Fracture evaluation showed 84 % accuracy, with CT and 3D reconstruction proving valuable in assessing fragment displacement. Imaging revealed tendon ruptures, joint space narrowing, fluid accumulation, and edema in key anatomical regions. The algorithm facilitated early diagnosis and guided appropriate intervention, leading to favorable clinical outcomes. Its application in post-traumatic cases enabled precise localization of pathology, supporting both surgical and conservative management strategies. These findings underscore the importance of multimodal imaging and structured diagnostic pathways in optimizing outcomes for patients with subacromial impingement syndrome, and related shoulder injuries.

Key words: subacromial impingement syndrome, MRI, CT, shoulder injury, tendon rupture, diagnostic algorithm.

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МЕТОДИ ДІАГНОСТИЧНОЇ ВІЗУАЛІЗАЦІЇ ПРИ СУБАКРОМІАЛЬНОМУ ІМПІНДЖМЕНТ-СИНДРОМІ

У цьому дослідженні представлений структурований діагностичний алгоритм для субакроміального імпінджмент-синдрому, що включає методи рентгенографії, МРТ та КТ з акцентом на діагностичну точність та планування лікування. МРТ продемонструвала високу специфічність (100 %) та помірну чутливість (79 %) при діагностиці субакроміального імпінджмент-синдрому із загальною точністю 76 %. При оцінці переломів точність становила загалом 84 %, у своїй КТ з 3D-реконструкцією виявилася особливо корисною аналіз зміщення кісткових фрагментів. Візуалізація дозволила виявити розриви сухожиль, звуження суглобової щілини, скупчення рідини та набряк у ключових анатомічних зонах. Розроблений алгоритм сприяв ранній діагностиці та визначенню оптимальної тактики лікування, що забезпечило сприятливі клінічні результати. Застосування алгоритму в посттравматичних випадках дозволило точно локалізувати патологічне вогнище, що підвищило ефективність як хірургічних, так і консервативних втручань. Отримані дані підкреслюють значущість мультимодальної візуалізації та структурованих діагностичних підходів для оптимізації ведення пацієнтів із субакроміальним імпінджмент-синдромом та супутніми ушкодженнями плечового суглоба.

Ключові слова: субакроміальний імпінджмент-синдром, МРТ, КТ, травма плеча, розрив сухожилля, діагностичний алгоритм.

Shoulder pain is polyetiological in nature, contributes to a decline in quality of life (QoL), and necessitates a precise diagnostic approach to guide effective management. It affects up to 26 % of the global population, often caused by pathologies of the rotator cuff and periarticular tissues [1]. Subacromial impingement syndrome (SIS) is increasingly studied due to its impact on QoL leading to pain, inflammation, and eventual tendon degeneration.

Recent meta-analyses confirm that SIS accounts for over 60 % of shoulder-related clinical presentations. The multifactorial etiology includes biomechanical dysfunction, scapular dyskinesia, acromial morphology, and systemic factors such as obesity and diabetes mellitus. Advanced imaging modalities such as functional ultrasound (FUS) and high-resolution magnetic resonance imaging (MRI) now enable early detection of tendon degeneration and subacromial inflammation [9]. Studies published between 2020–2024 report mean diagnostic sensitivity of ~65 %, reinforcing the need for imaging confirmation. For example, the acromiohumeral distance (AHD) and critical shoulder angle (CSA) measured on standard anteroposterior X-ray image (AP radiographs) are reliable for preoperative planning. C. Neer outlined three stages of shoulder impingement.

Diagnosing SIS in patients with shoulder pain underscores the crucial role of radiological imaging in accurately triaging patients for either physiotherapy or surgical intervention, as well as in monitoring their progress following treatment. Clinically, distinguishing anterior–superior compression syndrome from subcoracoid impingement is challenging because both occur near the coracoid process of the scapula, and the exact location of pain often isn't clearly defined. Consequently, instrumental diagnostics, particularly imaging, play a pivotal role.

While MRI may reveal indirect signs such as degenerative or inflammatory changes in the anterosuperior rotator cuff, it cannot reliably confirm mechanical compression. On imaging, MRI can only

indirectly support a diagnosis of anterior–superior impingement by demonstrating inflammatory, degenerative, or traumatic changes in the anterosuperior rotator cuff. However, definitive confirmation of mechanical compression, tendon instability, and contact between the long-head biceps tendon and the anterosuperior glenoid typically requires high-resolution, functional ultrasound, particularly when paired with dynamic maneuvers and external stressors in the scanned region. Functional ultrasound with high-resolution probes has demonstrated excellent accuracy for detecting tendon instability, dynamic narrowing, and impingement during movement – outperforming static MRI in these functional contexts [6]. Dynamic ultrasound metrics, such as minimal acromiohumeral distance (mVAHD), consistently correlate with clinical outcomes and can quantitatively track anterior–superior impingement patterns [11]. Ultrasound reliability studies confirm that measurements of acromiohumeral distance and supraspinatus tendon morphology are reproducible between observers [3–5, 9, 10].

The purpose of the study was to develop an advanced algorithm for radiological diagnostic techniques in patients with subacromial impingement syndrome, including a comparative analysis of the diagnostic accuracy and effectiveness of various imaging modalities, and an evaluation of the clinical relevance of key radiological parameters.

Materials and methods. The study employs a mixed-method randomized design, encompassing both retrospective and prospective components. The retrospective arm included patients who underwent diagnostic evaluation within the past five years, while the prospective arm involved patients scheduled for examination over the forthcoming five-year period. This dual approach enabled comprehensive analysis of diagnostic trends and outcomes over an extended timeframe.

The study encompasses a cohort of 100 patients presenting with shoulder pain and clinically suspected SIS admitted to the Academician M.A. Topchubashov Scientific Surgical Center in 2014–2024. The study includes male and female patients aged between 16 and 73 years presented with shoulder pain and clinically suspected of having SIS; patients whose clinical and instrumental evaluations did not confirm SIS, as well as those with malignant pathologies, were excluded.

From chosen cohort, a control group comprising 20 individuals was established, while the remaining 80 patients comprised the primary study group. All participants underwent a comprehensive diagnostic protocol, including the collection of detailed anamnestic and clinical data, along with standard diagnostic assessments. Each patient underwent a combination of 2 to 3, or in some cases, all 4 radiological diagnostic modalities: conventional radiography (X-ray), Computed Tomography (CT), Ultrasonography (US), and Magnetic resonance imaging (MRI). This structured approach facilitated a rigorous comparative analysis of the diagnostic accuracy, utility, and clinical significance of each imaging modality in the context of SIS.

Differences in the general indicators were determined by Pearson's χ^2 and Fisher's exact criteria; comparison of average indicators carried out via Student's t- and Mann-Whitney U-criteria; values $p \leq 0.05$ considered statistically reliable. Mathematical calculations carried out using IBM SPSS Statistics 22 program.

Results of the study and their discussion. An algorithm was developed for the radiological diagnosis of subacromial impingement syndrome, detailing the use of various imaging methods at different stages of the condition. Radiological techniques were systematically compared, and the specific imaging characteristics (semiotics) of the syndrome were thoroughly analyzed. Additionally, the study examined prognostic factors influencing surgical outcomes – such as subacromial decompression, bursectomy, and acromioplasty – including acromion morphology and the severity of clinical symptoms.

The diagnostic efficacy of magnetic resonance imaging (MRI) in delineating fracture typology was rigorously evaluated. The modality demonstrated a sensitivity of 80 % for osseous disruptions originating from the articular surface, and 70 % for those arising within the subacromial compartment. Specificity values were recorded at 90 % for articular surface fractures and 93 % for subacromial-origin fractures. The aggregate diagnostic accuracy across both fracture classifications was calculated at 84 %. Regarding predictive metrics, for lesions confined to the articular surface, the positive predictive value (PPV) reached 92 %, while the negative predictive value (NPV) was 75 %. In the context of subacromial fracture manifestations, the PPV was 87.5 %, and the NPV attained 82 %.

These data underscore MRI's robust specificity and moderate-to-high sensitivity in stratifying fracture etiology, with particularly elevated predictive validity for affirming the presence of osseous pathology in anatomically discrete shoulder compartments.

MRI demonstrated a sensitivity of 79 %, specificity of 100 %, and diagnostic accuracy of 76 % for identifying SIS. The PPV reached 100 %, while NPV was 17 %. MRI finding was defined as positive at the presence of edema or a combination of imaging signs localized to the subacromial bursa or acromial osteophytes.

Based on the analyses performed, it can be concluded that in cases where conventional radiography yields insufficient diagnostic information – particularly in patients presenting with large bulla fractures (observed in 4 cases) – the use of X-ray computed tomography (CT) is more appropriate to enhance diagnostic precision. Three-dimensional (3D) reconstruction of the humeral head is deemed both justified and clinically advantageous, as it enables precise assessment of bone fragment deformation, displacement magnitude, and directional shift.

Implementation of the developed diagnostic algorithm in the acute post-traumatic phase is strongly recommended. In all observed cases, this strategy facilitated timely and accurate diagnosis, enabled prompt initiation of appropriate treatment, and ultimately resulted in favorable long-term clinical outcomes – ranging from satisfactory to excellent.

To substantiate the validity and clinical reliability of our proposed diagnostic algorithm for SIS, we present two representative patient cases as illustrative examples.

Case 1. Shoulder impingement syndrome secondary to post-traumatic injury, with progressive involvement and visualization of additional anatomical structures over time. A 47-year-old male patient presented with post-traumatic chronic shoulder right pain, limited range of motion, and night discomfort. Initial radiography of the right shoulder girdle was inconclusive, failing to reveal definitive pathological signs. Under first-step US investigation, the biceps tendon was not distinctly visualized within its anatomical groove due to rupture and subsequent retraction (Fig. 1).

Upon distal translation of the probe along the mid-third of the arm, the retracted biceps tendon accompanied by a substantial peritendinous fluid collection had been identified. Application of the diagnostic algorithm led to the timely implementation of MRI, which revealed subacromial bursal edema and acromial osteophyte formation – criteria aligning with a positive diagnosis per our defined radiological semiotics. Below, the MRI examination of the right shoulder girdle is shown (Fig.2).

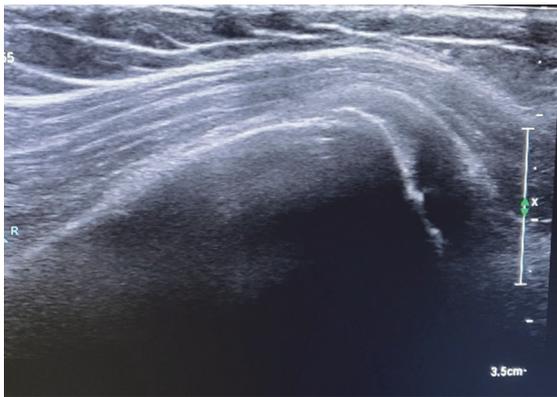


Fig. 1. Rupture of the supraspinatus tendon with an irregular and disrupted tendon contour.

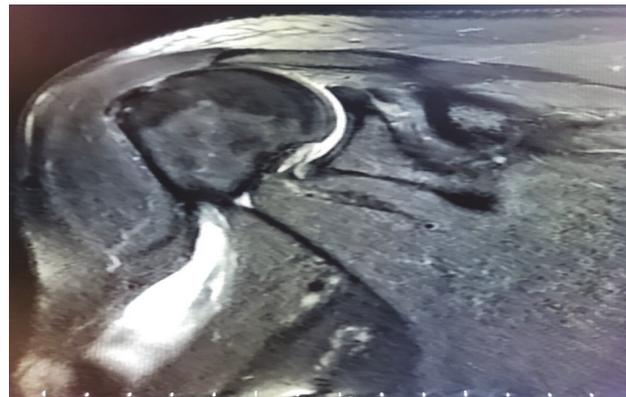


Fig. 2. Coronal PD FSE FSat. Partial subluxation of the humeral head with a reduced acromiohumeral interval.

Coronar PD FSE FSat revealed the concurrent rupture of the supraspinatus tendon, accompanied by retraction of the tendon of the long head of the biceps brachii following the tear, with surrounding post-hemorrhagic fluid accumulation. Strain (sprain) of the subscapularis tendon resulted in the edematous changes around the superior aspect of the acromioclavicular joint and fluid accumulation noted within the subcoracoid bursa. Surgical intervention (subacromial decompression and acromioplasty) was performed based on the algorithm's recommendations, resulting in full functional recovery and excellent clinical outcome at 6-month follow-up.

Case 2. A 53-year-old female patient reported subacute shoulder pain with activity-related exacerbation. The patient does not recall any significant traumatic event, the symptoms manifested following the lifting of heavy objects, and the pain was experienced when lifting the arm upward and backward. Diagnostic evaluations included X-ray, and magnetic resonance imaging (MRI). The diagnostic pathway, beginning with plain radiography – revealing mild acromial curvature (Fig.3) – and progressing to targeted MRI, confirmed SIS through findings of supraspinatus tendon thickening and signal intensity alterations, indicative of early tendinopathy and mechanical impingement (Fig.4).

Coronar PD FSE FSat of localized area revealed hyperintense signal observed within the supraspinatus tendon. Mild fluid accumulation noted in the subacromial bursa. Sagittal PD FSE FSat view helped to detect the fluid accumulation beneath the deltoid muscle, adjacent to the anterolateral surface of the humeral head.

The patient was managed conservatively with physical therapy and corticosteroid injections, resulting in significant symptom relief and a satisfactory long-term outcome.

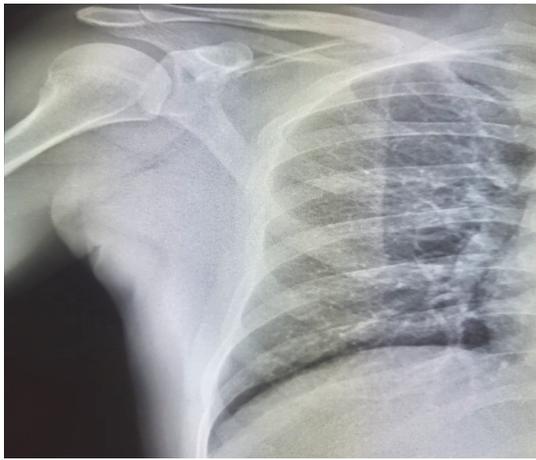


Fig. 3. The X-ray appears unremarkable, with findings assessed as within normal limits (reportedly).

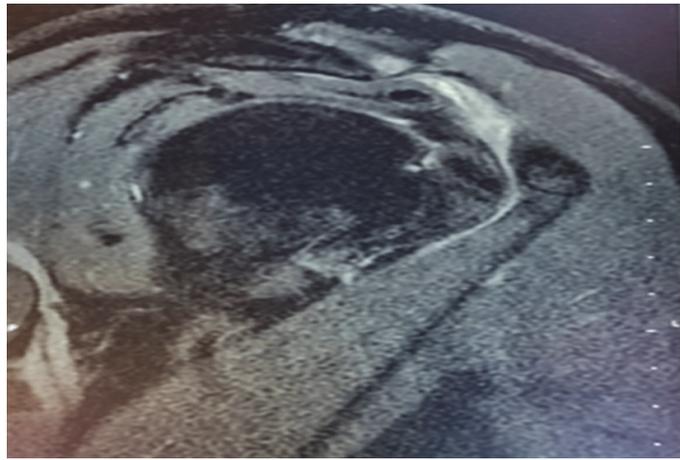


Fig. 4. Sagittal PD FSE FSat view: Fluid accumulation is present beneath the deltoid muscle, adjacent to the anterolateral aspect of the humeral head, with extension of the fluid along the supraspinatus tendon.

These cases confirm that the used algorithm facilitates early and accurate diagnosis, ensures appropriate modality selection, and supports timely therapeutic decision-making, thereby optimizing patient outcomes.

SIS remains one of the most frequent causes of shoulder pain, responsible for up to 60 % of shoulder-related complaints in orthopedic practice. The present study systematically compared radiological diagnostic modalities – conventional radiography, ultrasound, CT, and MRI – in order to establish a structured algorithm for SIS diagnostics. Our findings demonstrate that multimodal imaging, when sequenced in a structured diagnostic pathway, provides a high level of diagnostic accuracy and ensures both timely recognition of pathology and informed clinical decision-making.

The diagnostic performance of MRI in our cohort (sensitivity 79 %, specificity 100 %, accuracy 76 %) is consistent with published data. Previous meta-analyses have reported mean sensitivities between 70–85 % and specificities approaching 95–100 % for SIS and associated rotator cuff pathologies [7]. This concordance reinforces the role of MRI as the cornerstone modality for definitive evaluation of tendon ruptures, bursitis, and bony impingement signs. Dynamic ultrasound, though not the central focus of our algorithm, has been increasingly highlighted in recent literature as a valuable complement to MRI. For example, Ashour et al. demonstrated that dynamic ultrasonography achieved higher sensitivity than static MRI in detecting tendon instability and functional narrowing during motion [2]. Similar reliability findings were confirmed by Bağcıer et al., who validated interobserver reproducibility in acromiohumeral distance and supraspinatus tendon morphology measurements [4]. Our data suggest that while MRI provides unparalleled anatomical detail, ultrasound is better suited to functional assessments, particularly in early-stage SIS when dynamic impingement is present but static imaging appears equivocal.

The diagnostic role of CT with three-dimensional (3D) reconstruction was emphasized in our study for fracture evaluation, with an accuracy of 84 %. This finding aligns with recent reports that CT is indispensable in characterizing fragment displacement and osseous geometry, especially in cases where radiographs are inconclusive. Zubair, M et al. underscored that advanced cross-sectional modalities not only improve diagnostic yield but also contribute to preoperative surgical planning [13].

Our structured algorithm demonstrated particular utility in guiding both conservative and surgical interventions. In Case 1, the integration of ultrasound and MRI identified tendon rupture and subacromial bursitis, leading to surgical decompression and acromioplasty with excellent outcomes. Conversely, Case 2 exemplified the utility of imaging in stratifying patients to conservative management, as early tendinopathy without severe structural compromise was detected.

The prognostic implications of imaging-based stratification cannot be overstated. Wu et al. have recently highlighted that quantitative ultrasonographic metrics, such as mVAHD, predict response to dual-target injections in SIS patients [12]. By integrating such parameters into our algorithm, future refinements could expand predictive accuracy for therapeutic outcomes, tailoring management more precisely to individual patients.

A further strength of our findings lies in correlating imaging data with biomechanical and systemic risk factors for SIS. Obesity, diabetes, and scapular dyskinesia have all been identified as contributors to the pathophysiology of SIS [8]. While these factors were not directly stratified in our study, the reproducibility of our imaging protocol across patients with heterogeneous clinical backgrounds supports its robustness.

Notably, imaging allowed us to differentiate SIS from anterior–superior compression and subcoracoid impingement syndromes, which are often clinically indistinguishable. The ability to visualize edema, tendon instability, and contact points via MRI and dynamic ultrasound is critical to avoiding misclassification and ensuring that surgical interventions are directed appropriately [12].

Despite these strengths, several limitations must be acknowledged. First, while MRI demonstrated high specificity, its relatively low negative predictive value (17 %) highlights that negative findings cannot exclude SIS, particularly in early functional stages. This limitation underscores the importance of combining MRI with dynamic ultrasound in equivocal cases. Second, although CT was highly accurate for fractures, radiation exposure remains a concern, especially in younger populations. Finally, while our cohort was sizable (n=100), larger multicenter studies would be required to validate the generalizability of the proposed algorithm across diverse healthcare settings.

Conclusions

1. MRI demonstrated high specificity (100 %) and moderate sensitivity (79 %) in the diagnosis of subacromial impingement syndrome (SIS), with a diagnostic accuracy of 76 %.

2. PPV was 100 %, while NPV was 17 %, indicating strong reliability in confirming SIS when MRI findings are positive.

3. Diagnostic performance of MRI in fracture classification showed:

A – Articular surface fractures: Sensitivity 80 %, specificity 90 %, PPV 92 %, NPV 75 %.

B – Subacromial space fractures: Sensitivity 70 %, specificity 93 %, PPV 87.5 %, NPV 82 %.

C – Overall diagnostic accuracy for both types was 84 %.

The proposed diagnostic algorithm for SIS proved effective in guiding the stepwise use of imaging modalities, ensuring early and accurate diagnosis. Radiography alone may be insufficient in cases with subtle or complex pathology, highlighting the importance of MRI and CT – especially with 3D reconstruction – for detailed anatomical evaluation. Early application of this algorithm post-injury enabled precise identification of soft tissue and osseous abnormalities, supported appropriate treatment planning (surgical or conservative), and contributed to favorable long-term clinical outcomes. These findings validate the clinical utility of a structured imaging approach in the management of SIS and related shoulder pathologies.

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