

Association between preoperative proximal humeral Hounsfield unit values and structural healing after arthroscopic rotator cuff repair: a retrospective cohort study

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Abstract

Background: Local bone quality may influence suture-anchor fixation and tendon-to-bone healing after arthroscopic rotator cuff repair (ARCR). Hounsfield unit (HU) values derived from computed tomography (CT) may provide a quantitative surrogate measure of regional cancellous bone quality. We investigated the association between preoperative proximal humeral HU values and 12-month structural healing after ARCR and assessed the discriminative performance of HU values for unfavorable structural healing.

Methods: This single-center retrospective cohort study included 126 patients with full-thickness supraspinatus tears who underwent primary arthroscopic suture-bridge repair between January 2020 and December 2024 and had both preoperative shoulder CT and 12-month postoperative magnetic resonance imaging (MRI). Proximal humeral HU values were calculated as the mean of measurements obtained at three equidistant axial cancellous-bone levels between the humeral head apex and the surgical neck. Structural integrity was assessed using the Sugaya classification. Sugaya types I–II were categorized as favorable healing and types III–V as unfavorable healing. Group comparisons, Spearman rank correlation, multivariable logistic regression with HU modeled per 10-unit increase, and receiver operating characteristic (ROC) analysis were performed.

Results: Of the 126 patients, 78 had favorable structural healing and 48 had unfavorable structural healing. Mean proximal humeral HU values were lower in the unfavorable-healing group than in the favorable-healing group (63.67 ± 31.82 vs 90.54 ± 38.43 , $P < 0.001$). HU values were moderately inversely correlated with Sugaya grade (Spearman $\rho = -0.425$, $P < 0.001$). After adjustment for age, tear size, Goutallier grade, and supraspinatus muscle occupation ratio (SGOR), each 10-HU increase was associated with lower odds of unfavorable structural healing (adjusted OR, 0.822; 95% CI, 0.682–0.990; $P = 0.039$). Larger tear size was independently associated with higher odds of unfavorable healing, whereas higher SGOR was associated with lower odds. The AUC for HU values was 0.784. An exploratory cutoff of 87.5 HU yielded a sensitivity of 85.1% and a specificity of 51.3%.

Conclusions: Lower preoperative proximal humeral HU values were independently associated with unfavorable structural healing at 12 months after ARCR. Opportunistic HU assessment may provide complementary information on local bone-related risk; however, its modest specificity suggests that HU values should be interpreted alongside tear size and muscle-quality measures rather than as a standalone diagnostic threshold.

Background

Rotator cuff tears are a common cause of shoulder pain and functional impairment, with their prevalence increasing substantially with age [1, 2]. Arthroscopic rotator cuff repair (ARCR) can provide substantial improvements in pain and function; however, postoperative tendon integrity is not consistently maintained. Structural healing failure and recurrent tearing remain clinically important because they may compromise strength, endurance, patient satisfaction, and the durability of recovery [3–5].

Postoperative magnetic resonance imaging (MRI) is widely used to assess the structural integrity of repaired rotator cuff tendons. The Sugaya classification categorizes postoperative tendon morphology from type I to type V according to tendon thickness, signal intensity, and continuity [3]. Although the clinical significance of type III tendons—which remain continuous but demonstrate reduced thickness—remains debated, previous structural outcome studies have categorized types I–II as favorable healing and types III–V as unfavorable healing [6, 7]. This dichotomization therefore encompasses both definite tendon discontinuity and structurally suboptimal but continuous tendons, a distinction that should be retained when interpreting the findings.

Established determinants of tendon healing after ARCR include tear size, tendon retraction, fatty infiltration, muscle atrophy, age, and repair tension [4, 8–11]. Bone-related factors have also received increasing attention because early repair stability depends partly on suture-anchor fixation within the greater tuberosity. Cadaveric biomechanical studies have demonstrated that suture-anchor pullout strength varies according to local bone mineral density and implant location and is further influenced by anchor design [12, 13]. Despite the potential relevance of bone quality to repair stability, osteoporosis screening remains underused before rotator cuff repair [14, 15].

Dual-energy X-ray absorptiometry (DXA) remains the reference standard for systemic bone mineral density assessment but does not directly characterize regional cancellous bone quality at the intended anchor site. Hounsfield unit (HU) values derived from computed tomography (CT) can be obtained opportunistically from existing shoulder CT examinations and may provide a continuous surrogate measure of regional bone quality without additional imaging [16–18]. Recent studies support the potential use of proximal humeral HU values as markers of low regional or systemic bone density in patients undergoing shoulder surgery [16–18]. However, the association between preoperative proximal humeral HU values and postoperative tendon structural integrity after ARCR remains incompletely characterized.

Accordingly, the primary objective of this study was to evaluate the association between preoperative proximal humeral HU values and MRI-assessed structural healing at 12 months after ARCR. The secondary objective was to assess the discriminative performance of proximal humeral HU values and to derive an exploratory cutoff for identifying unfavorable structural healing. We hypothesized that lower preoperative proximal humeral HU values would be independently associated with less favorable postoperative structural integrity.

Methods

Study design and setting

This retrospective, single-center cohort study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement who underwent treatment in the Department of Sports Medicine, People's Hospital of Ningxia Hui Autonomous Region, between

January 2020 and December 2024. According to the study flow, no a priori sample-size calculation was performed; instead, all consecutive patients who met the eligibility criteria during the predefined study period were included. The study was approved by the Ethics Committee of Ningxia Hui Autonomous Region People's Hospital (Approval No. 2026-LL-104). The requirement for written informed consent was waived in accordance with national legislation and institutional requirements for retrospective cohort studies. Because this was a retrospective observational cohort study rather than a prospective interventional clinical trial, clinical trial registration was not applicable.

Inclusion and exclusion criteria

Patients were eligible if they (1) had a full-thickness supraspinatus tear confirmed by preoperative MRI and supported by clinical and radiographic findings; (2) underwent primary ARCR; and (3) had an available preoperative CT examination of the affected shoulder and postoperative MRI at 12 months.

Patients were excluded if they had (1) a massive rotator cuff tear involving full-thickness tears of at least two tendons according to the Gerber definition; (2) previous surgery or fracture of the ipsilateral shoulder; (3) shoulder instability, inflammatory or degenerative arthritis, bone tumors, neurological disease, or systemic disease affecting shoulder function; (4) previous pharmacological or non-pharmacological treatment for osteoporosis other than basic supplementation; (5) long-term use of medications affecting calcium or bone metabolism; or (6) documented substance abuse within the preceding year.

Surgical procedure and rehabilitation

All procedures were performed by the same surgical team with patients under general anesthesia combined with a brachial plexus block, positioned in the lateral decubitus position with the affected arm under traction. Standard posterior, anterior, lateral, and posterolateral arthroscopic portals were used. The glenohumeral joint and subacromial space were systematically evaluated for tear size and configuration, tendon quality, and concomitant pathology. Inflamed synovial and bursal tissue and nonviable tendon tissue were debrided, followed by preparation of the tendon edge and greater tuberosity footprint. Subacromial decompression and acromioplasty were performed when clinically indicated on the basis of acromial morphology and evidence of impingement. The supraspinatus tear was repaired using a suture-bridge technique to restore tendon-to-footprint contact.

Postoperatively, the operated shoulder was immobilized using an abduction brace. A staged rehabilitation protocol was used, consisting of protected passive motion followed by assisted active motion and subsequent resisted strengthening. Progression through the rehabilitation protocol was individualized according to tear size, intraoperative repair tension, and the treating surgeon's clinical assessment.

Imaging acquisition

Shoulder MRI was performed on 3.0-T MRI system (Ingenia 3.0T CX; Philips) equipped with a dedicated shoulder surface coil. The protocol included oblique coronal and oblique sagittal T1-weighted, proton-density-weighted, and fat-suppressed T2-weighted sequences, together with axial fat-suppressed T2-weighted imaging. CT examinations were performed using a 256-slice CT scanner (Brilliance iCT; Philips), with patients positioned supine and the affected shoulder maintained in a neutral position. The CT acquisition range extended from approximately 2 cm superior to the acromion to 3 cm inferior to the surgical neck.

Primary outcome: structural healing

At 12 months postoperatively, two musculoskeletal radiologists, each with more than 5 years of experience, assessed repaired tendon integrity according to the Sugaya classification (Fig. 2): type I, sufficient tendon thickness with homogeneous low signal; type II, sufficient thickness with partial high signal; type III, insufficient thickness without discontinuity; type IV, a small discontinuity; and type V, a medium or large discontinuity [3]. Sugaya types I–II were categorized as favorable structural healing, whereas types III–V were categorized as unfavorable structural healing for the primary binary analysis.

Proximal humeral HU measurement

Preoperative CT images were evaluated using multiplanar reconstructions. Along the longitudinal axis of the humerus, the region extending from the humeral head apex to the surgical neck was divided into four equal segments. The resulting three equidistant axial levels were used for HU measurement. At each level, a region of interest (ROI) was manually placed within cancellous bone, with care taken to exclude cortical bone, calcification, cystic changes, sclerosis, and imaging artifacts. The mean of the three HU measurements was recorded as the proximal humeral HU value for each patient (Fig. 3).

Other variables and measurements

Collected variables included age at surgery, sex, body mass index (BMI), symptom duration, smoking history, alcohol consumption, affected side, acromial morphology, tear size, Goutallier grade of fatty infiltration, supraspinatus muscle occupation ratio (SGOR), and proximal humeral HU value. Tear size was recorded as the maximum tear diameter measured on preoperative MRI or during arthroscopy; when the two measurements differed, the intraoperative arthroscopic measurement was used preferentially. Acromial morphology was classified according to the Bigliani classification.

Supraspinatus fatty infiltration was graded from 0 to 4 according to the Goutallier classification on an oblique sagittal MRI image obtained near the scapular Y-view [8–10]. SGOR was measured on the oblique sagittal MRI image showing the largest cross-sectional area of the supraspinatus muscle belly and clearly identifiable anatomical landmarks. The supraspinatus muscle and supraspinatus fossa areas

were manually delineated three times, and the respective measurements were averaged. SGOR was calculated as the supraspinatus muscle cross-sectional area divided by the supraspinatus fossa area and expressed as a percentage (Fig. 4) [11].

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp). The distribution of continuous variables was assessed for normality. Normally distributed variables were summarized as mean $\pm$ standard deviation (SD) and compared using the independent-samples t-test, with Welch correction applied as appropriate. Non-normally distributed variables were summarized as the median and interquartile range (IQR) and compared using the Mann–Whitney U test. Categorical variables were summarized as counts and percentages and compared using the χ^2 test or Fisher's exact test, as appropriate.

Spearman rank correlation was used to evaluate associations between proximal humeral HU values and Sugaya grade, age, tear size, Goutallier grade, and SGOR. Binary logistic regression was performed with unfavorable structural healing (Sugaya III–V) as the dependent variable. HU was modeled per 10-unit increase to facilitate clinical interpretation of the effect estimate. The multivariable logistic regression model included age, proximal humeral HU value, tear size, Goutallier grade, and SGOR. Odds ratios (ORs) with 95% confidence intervals (CIs) and P values were reported.

Receiver operating characteristic (ROC) analysis was used to assess the ability of proximal humeral HU values to discriminate between favorable and unfavorable structural healing. The area under the ROC curve (AUC) was calculated, and an exploratory HU cutoff was derived using the Youden index. Sensitivity and specificity at the exploratory cutoff were reported. All statistical tests were two-sided, with $P < 0.05$ considered statistically significant.

Results

A total of 126 patients were included in the final analysis (Fig. 1). At 12 months, 78 patients (61.9%) were classified as having favorable structural healing and 48 (38.1%) as having unfavorable structural healing. The distribution of Sugaya grades at 12 months was type I in 28 patients (22.2%), type II in 50 (39.7%), type III in 41 (32.5%), type IV in 6 (4.8%), and type V in 1 (0.8%) (Table 2). Sugaya type III accounted for 32.5% of the cohort, whereas types IV–V together accounted for 5.6% (Table 2).

Table 2
Distribution of Sugaya grades at 12 months after arthroscopic rotator cuff repair

Sugaya grade	n (%)
I	28 (22.2)
II	50 (39.7)
III	41 (32.5)
IV	6 (4.8)
V	1 (0.8)
Sugaya I-II was categorized as favorable healing; Sugaya III-V as unfavorable healing.	

Baseline and imaging characteristics

Compared with patients with favorable structural healing, those with unfavorable structural healing were older and had longer symptom duration, larger tears, lower SGOR, lower proximal humeral HU values, and higher Goutallier grades (Table 1). Mean proximal humeral HU values were 90.54 ± 38.43 in the favorable structural-healing group and 63.67 ± 31.82 in the unfavorable structural-healing group ($P < 0.001$). No statistically significant between-group differences were observed in body mass index, sex, smoking status, alcohol consumption, affected side, or acromial type.

Table 1

Baseline clinical and imaging characteristics according to 12-month structural healing status

Characteristic	Favorable healing (n = 78)	Unfavorable healing (n = 48)	P value
Age, years	54.94 ± 8.47	59.46 ± 6.59	0.001
Body mass index, kg/m ²	24.19 ± 2.94	24.63 ± 2.99	0.426
Symptom duration, months	3.00 (1.00, 6.00)	6.00 (2.00, 10.00)	0.048
Tear size, cm	2.00 (2.00, 2.80)	3.00 (2.00, 3.50)	< 0.001
SGOR, %	63.63 ± 12.48	52.15 ± 11.69	< 0.001
Proximal humeral HU value	90.54 ± 38.43	63.67 ± 31.82	< 0.001
Smoking, n (%)	11 (14.1)	7 (14.5)	0.940
Alcohol consumption, n (%)	4 (5.1)	3 (6.3)	0.789
Sex, n (%)			0.126
Male	28 (35.9)	11 (22.9)	
Female	50 (64.1)	37 (77.1)	
Affected side, n (%)			0.446
Left	18 (23.1)	14 (29.2)	
Right	60 (76.9)	34 (70.8)	
Acromial type, n (%)			0.594
Type I	1 (1.3)	1 (2.1)	
Type II	57 (73.1)	31 (64.6)	
Type III	20 (25.6)	16 (33.3)	
Goutallier grade, n (%)			< 0.001
Grade 0	15 (19.2)	5 (10.4)	
Grade 1	30 (38.5)	9 (18.8)	
Grade 2	26 (33.3)	16 (33.3)	
Grade 3	7 (9.0)	18 (37.5)	
Values are mean ± standard deviation, median (Q1, Q3), or n (%). HU, Hounsfield unit; SGOR, supraspinatus muscle occupation ratio.			

Correlations with proximal humeral HU values

Proximal humeral HU values were moderately inversely correlated with Sugaya grade (Spearman $\rho = -0.425$, $P < 0.001$) and age ($\rho = -0.442$, $P < 0.001$). HU values were weakly inversely correlated with tear size ($\rho = -0.219$, $P = 0.015$) and weakly positively correlated with SGOR ($\rho = 0.185$, $P = 0.041$). The association between HU values and Goutallier grade was not statistically significant ($\rho = -0.165$, $P = 0.068$) (Table 3).

Table 3
Spearman rank correlations between proximal humeral Hounsfield unit values and clinical and imaging variables

Variable	n	Spearman rho	P value
Sugaya grade	126	-0.425	< 0.001
Age	126	-0.442	< 0.001
Tear size	126	-0.219	0.015
Goutallier grade	126	-0.165	0.068
SGOR	126	0.185	0.041
Negative rho values indicate an inverse association with proximal humeral HU values.			

Logistic regression

In univariable analysis, each 10-HU increase in proximal humeral HU value was associated with lower odds of unfavorable structural healing (OR, 0.801; 95% CI, 0.709–0.905; $P < 0.001$). After adjustment for age, tear size, Goutallier grade, and SGOR, proximal humeral HU value remained independently associated with unfavorable structural healing (adjusted OR per 10-HU increase, 0.822; 95% CI, 0.682–0.990; $P = 0.039$). Larger tear size was associated with higher odds of unfavorable structural healing (adjusted OR per 1-cm increase, 1.982; 95% CI, 1.082–3.630; $P = 0.027$), whereas higher SGOR was associated with lower odds (adjusted OR per 1-percentage-point increase, 0.932; 95% CI, 0.892–0.974; $P = 0.002$). Age and Goutallier grade were not independently associated with unfavorable structural healing in the multivariable model (Table 4).

Table 4
Univariable and multivariable logistic regression analyses of unfavorable structural healing

Variable	Odds ratio	95% confidence interval	P value
Univariable: HU per 10-unit increase	0.801	0.709–0.905	< 0.001
Multivariable: age per year	0.997	0.924–1.076	0.941
Multivariable: HU per 10-unit increase	0.822	0.682–0.990	0.039
Multivariable: tear size per cm	1.982	1.082–3.630	0.027
Multivariable: Goutallier grade per grade	1.152	0.672–1.975	0.607
Multivariable: SGOR per 1%	0.932	0.892–0.974	0.002
Outcome: Sugaya III-V. The multivariable model included age, HU, tear size, Goutallier grade, and SGOR. OR < 1 indicates lower odds of unfavorable healing.			

Table 5
Discriminative performance of proximal humeral Hounsfield unit values for unfavorable structural healing

Measure	Value
Area under the curve	0.784
Youden cutoff	87.5 HU
Sensitivity	0.851
Specificity	0.513
Positive outcome: Sugaya III-V. Lower HU values indicated greater structural risk.	

ROC analysis

Proximal humeral HU values demonstrated moderate discrimination for unfavorable structural healing, with an AUC of 0.784 (Figure 5). The exploratory Youden index–derived cutoff of 87.5 HU yielded a sensitivity of 85.1% and a specificity of 51.3% (Table 5).

Discussion

In this retrospective cohort, lower preoperative proximal humeral HU values were independently associated with unfavorable structural healing at 12 months after ARCR. HU values were lower in the unfavorable-healing group, were inversely correlated with Sugaya grade, and remained independently associated with the outcome after adjustment for age, tear size, Goutallier grade, and SGOR. Tear size and SGOR were also independently associated with structural healing, suggesting that bone-related, tendon-related, and muscle-related characteristics may provide complementary information regarding postoperative tendon integrity.

The observed association is biologically and biomechanically plausible. Initial stability after rotator cuff repair depends partly on suture-anchor fixation within the cancellous bone of the greater tuberosity. Experimental studies have demonstrated that suture-anchor pullout strength varies according to local bone mineral density and anchor position and is also influenced by anchor design [12, 13, 20, 21]. Lower HU values may reflect lower cancellous-bone density and potentially poorer regional bone quality. Such bone characteristics could theoretically compromise anchor fixation and increase micromotion at the repair footprint, thereby creating less favorable mechanical conditions for tendon-to-bone healing.

Bone quality may also be relevant to the biological environment of tendon-to-bone healing. Osteoporotic bone is characterized not only by reduced bone mass but also by alterations in bone remodeling, vascularity, and cellular signaling. These alterations may adversely affect mineralization and maturation at the tendon-to-bone interface [26, 30]. Clinical and experimental studies of osteoporosis in the setting of rotator cuff repair similarly suggest that poor bone quality may be associated with impaired fixation and healing [26, 30, 34, 35]. The present findings add clinical observational evidence by demonstrating an association between a routinely available regional CT-derived measure and postoperative MRI-assessed tendon structure.

The study definition of unfavorable structural healing requires careful interpretation, particularly with respect to Sugaya type III tendons. Of the 48 patients classified as having unfavorable structural healing, 41 had Sugaya type III morphology, whereas only 7 had type IV or V tendon discontinuity. Sugaya type III represents a continuous but thinned tendon and therefore should not be considered synonymous with definite retear. Previous studies have highlighted both limitations in the reproducibility of Sugaya grading and uncertainty regarding the clinical significance of type III morphology [6, 7]. More recent evidence suggests that some type III tendons may subsequently progress to retear, particularly in patients with larger tears or greater fatty degeneration [22]. Accordingly, the binary endpoint used in this study is more appropriately interpreted as unfavorable structural healing rather than definite repair failure or retear.

The reported timing of postoperative structural failure also underscores the potential relevance of preoperative risk assessment. Serial imaging studies indicate that retears occur predominantly during the early and intermediate postoperative healing periods, although their timing varies according to tear size [5, 19, 23, 24]. Patients with lower HU values may theoretically have a less favorable bone–anchor environment during this period. The present findings do not establish that modifying anchor selection, bone-health management, or rehabilitation on the basis of HU values improves clinical or structural outcomes; however, they provide a rationale for prospective evaluation of these strategies.

The observed associations of tear size and SGOR with structural healing are consistent with previous studies of rotator cuff repair outcomes. Larger tears generally require greater mobilization and may be associated with greater repair tension, poorer tendon quality, and higher rates of structural failure [4, 25, 28, 29]. Supraspinatus muscle atrophy and fatty degeneration have also been associated with reparability and postoperative tendon integrity [8–11, 27, 36]. In the present multivariable model, higher SGOR remained independently associated with lower odds of unfavorable structural healing, whereas

Goutallier grade was not independently associated with the outcome. One possible explanation is that a continuous muscle-area measure such as SGOR may capture gradations in muscle atrophy that are not fully represented by an ordinal fatty-infiltration scale; however, correlations among imaging variables and the limited sample size may also have influenced the estimates.

ROC analysis demonstrated moderate discrimination of proximal humeral HU values for unfavorable structural healing. The exploratory 87.5-HU cutoff showed relatively high sensitivity (85.1%) but modest specificity (51.3%) and was both derived and evaluated in the same cohort. It should therefore be regarded as an exploratory within-cohort threshold rather than a validated diagnostic or treatment-decision threshold. Absolute HU values may vary according to tube voltage, reconstruction algorithm, slice thickness, scanner calibration, and ROI methodology [16–18, 31–33]. Accordingly, standardized CT acquisition and HU measurement protocols, internal validation, and external validation are required before a broadly applicable threshold can be proposed.

From a clinical perspective, opportunistic HU assessment may complement, rather than replace, established methods of systemic bone-health evaluation. DXA remains the reference standard for osteoporosis diagnosis and fracture-risk assessment, whereas proximal humeral HU values may provide additional information regarding regional bone quality in the operative shoulder [16–18, 31–33]. In patients with low proximal humeral HU values, formal bone-health assessment and additional consideration of bone quality during preoperative planning may be reasonable areas for further clinical evaluation. Biomechanical augmentation and cement-assisted anchor techniques have been investigated in poor-quality bone [37, 38], and emerging clinical and preclinical evidence suggests that anti-osteoporosis therapies may influence tendon-to-bone healing in selected settings [39–41]. None of these interventions was evaluated in the present cohort; therefore, treatment recommendations should not be inferred from the observed association between HU values and structural healing.

Limitations

This study has several limitations. First, the retrospective, single-center design introduces the possibility of selection bias and limits the generalizability of the findings. In addition, potentially relevant operative characteristics, including anchor model, number, material, insertion torque, and repair tension, were not fully incorporated into the analysis, although all procedures were performed by the same surgical team using a standardized suture-bridge technique. Second, detailed CT acquisition and reconstruction parameters that may influence absolute HU values were not available for analysis, which limits reproducibility and cross-center generalizability. Third, interobserver and intraobserver reliability of HU and SGOR measurements and of Goutallier and Sugaya grading was not assessed. Fourth, the primary endpoint was MRI-defined structural morphology rather than patient-reported symptoms, functional outcomes, strength, or range of motion; therefore, the present findings should not be interpreted as evidence of clinical outcome differences. Fifth, the ROC-derived cutoff and discrimination estimate were obtained from the same cohort without internal resampling or external validation and may therefore be

optimistic. Finally, only 7 patients had definite tendon discontinuity classified as Sugaya IV–V, precluding a stable multivariable analysis of definite retear as a separate outcome.

Future prospective multicenter studies should use standardized CT acquisition and HU measurement protocols, formally assess measurement reliability, incorporate patient-reported and functional outcomes, and evaluate whether HU values provide incremental information beyond established clinical and imaging factors. Internal resampling, calibration assessment, decision-curve analysis, and independent external validation would further clarify the robustness and potential clinical utility of HU-based risk assessment.

Conclusions

Lower preoperative proximal humeral HU values were independently associated with unfavorable structural healing at 12 months after ARCR. Opportunistic HU assessment may provide complementary information regarding regional bone-related risk when interpreted alongside tear size and supraspinatus muscle status. The exploratory HU cutoff requires standardized CT acquisition and measurement protocols, as well as independent validation, before it can be considered for routine clinical adoption.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Ningxia Hui Autonomous Region People's Hospital (Approval No. 2026-LL-104) and conducted in accordance with the Declaration of Helsinki and relevant national and institutional ethical requirements. Owing to the retrospective study design and use of anonymized clinical and imaging data, the Ethics Committee of Ningxia Hui Autonomous Region People's Hospital waived the requirement for written informed consent.

Consent for publication

All authors consent to the publication of this study.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available because they contain potentially identifiable clinical and imaging information. De-identified data may be available from the corresponding author upon reasonable request, subject to approval by the institutional ethics committee.

Competing interests

The authors declare no competing interests.

Clinical trial registration

Clinical trial number: not applicable.

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Authors’ contributions

YL: Conceptualization, Writing – original draft, Writing – review & editing. JXG: Conceptualization, Supervision, Writing – original draft. YC: Formal analysis, Methodology, Writing – review & editing. LLH: Conceptualization, Methodology, Resources, Writing – original draft. JCL: Data curation, Investigation, Writing – original draft. HJX: Data curation, Investigation, Methodology, Resources, Validation, Writing – review & editing. HQL: Investigation, Methodology, Software, Writing – original draft. KX: Data organization, Methodology, Writing – review & editing. XJM: Conceptualization, Methodology, Writing – review & editing. JW: Data curation, Formal analysis, Resources, Supervision, Writing – original draft, Writing – review & editing.

Statement

The work has not been published previously, is not under consideration for publication elsewhere, and has been approved by all authors.

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Figures

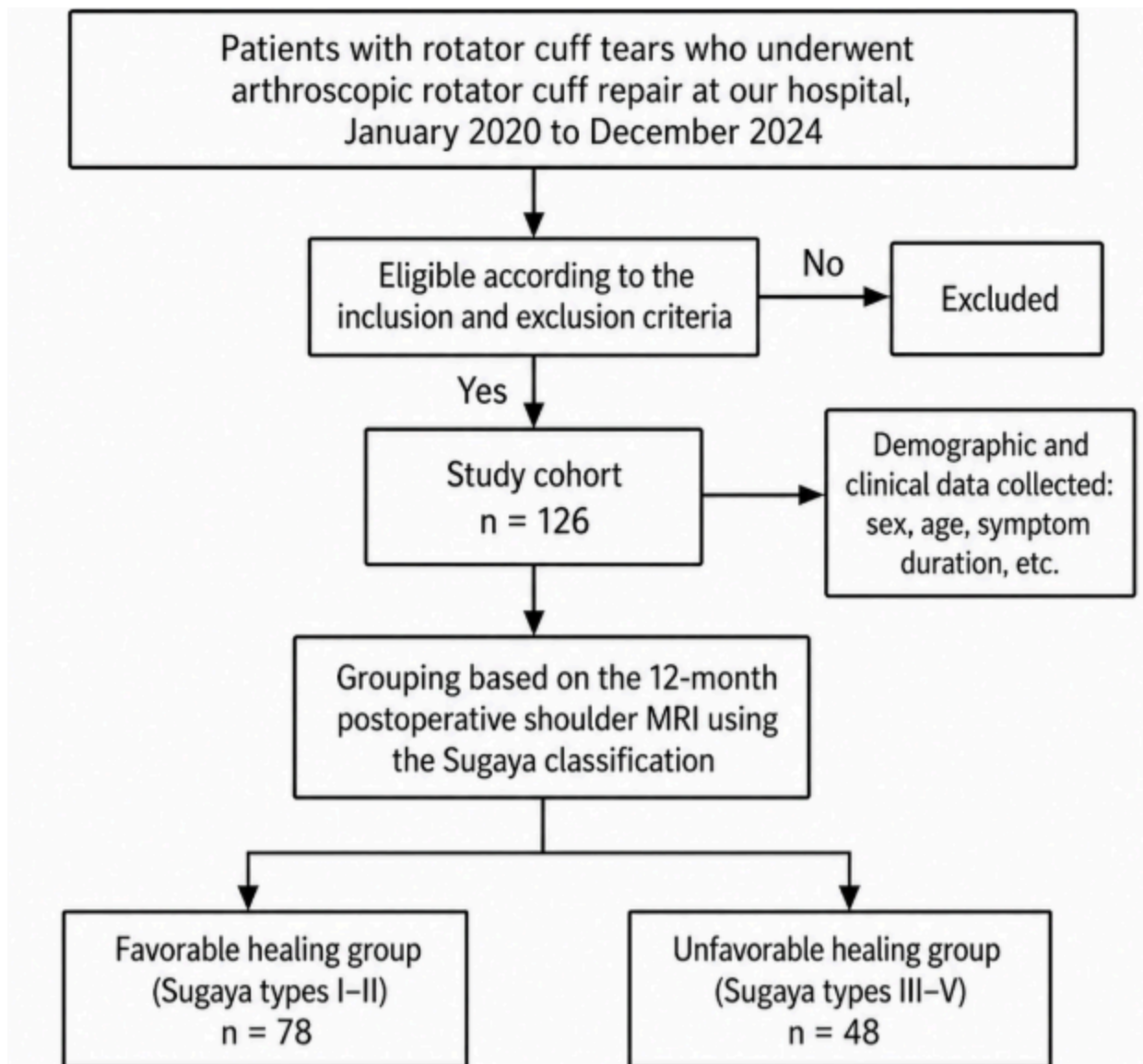


Figure 1

Flow diagram of patient selection and study cohort formation.

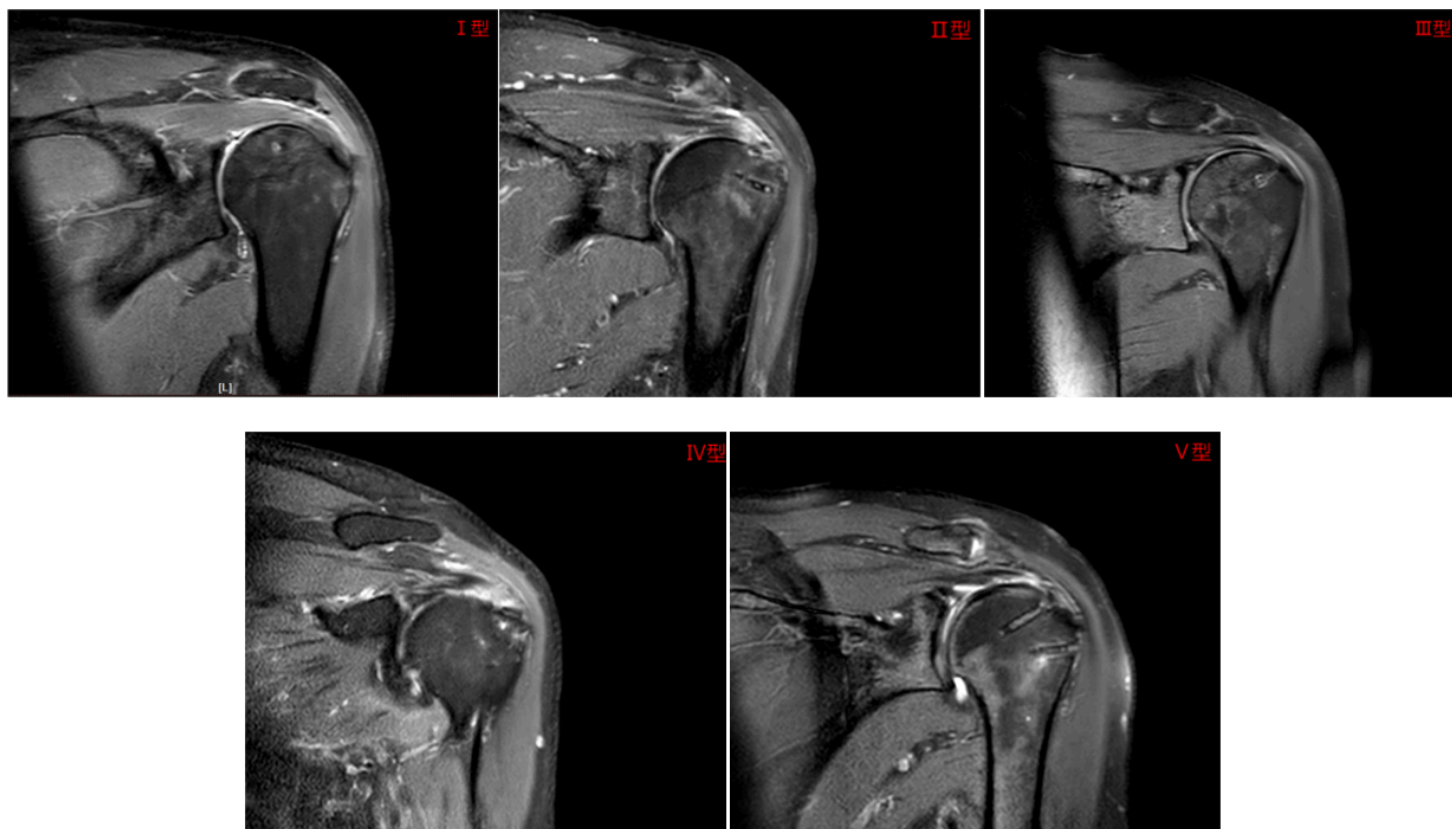


Figure 2

Postoperative MRI assessment of rotator cuff structural integrity according to the Sugaya classification.

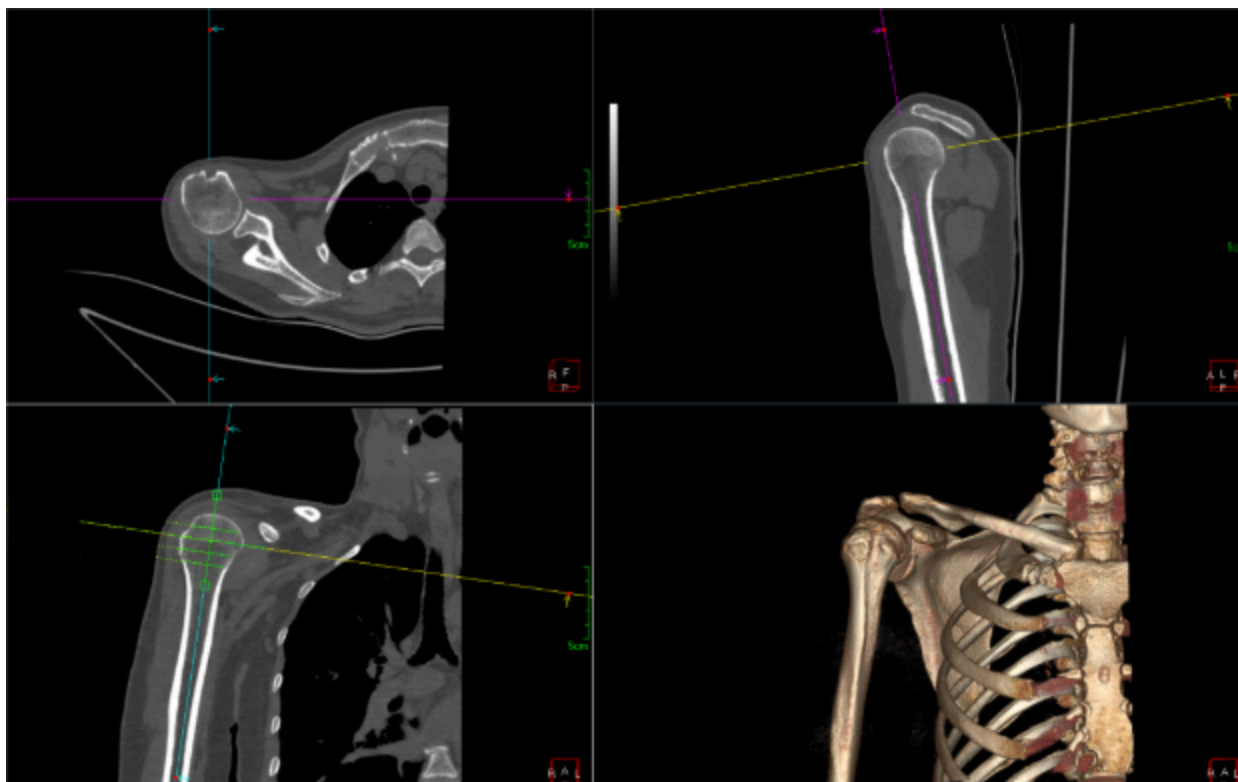


Figure 3

Measurement of proximal humeral Hounsfield unit values on preoperative computed tomography.

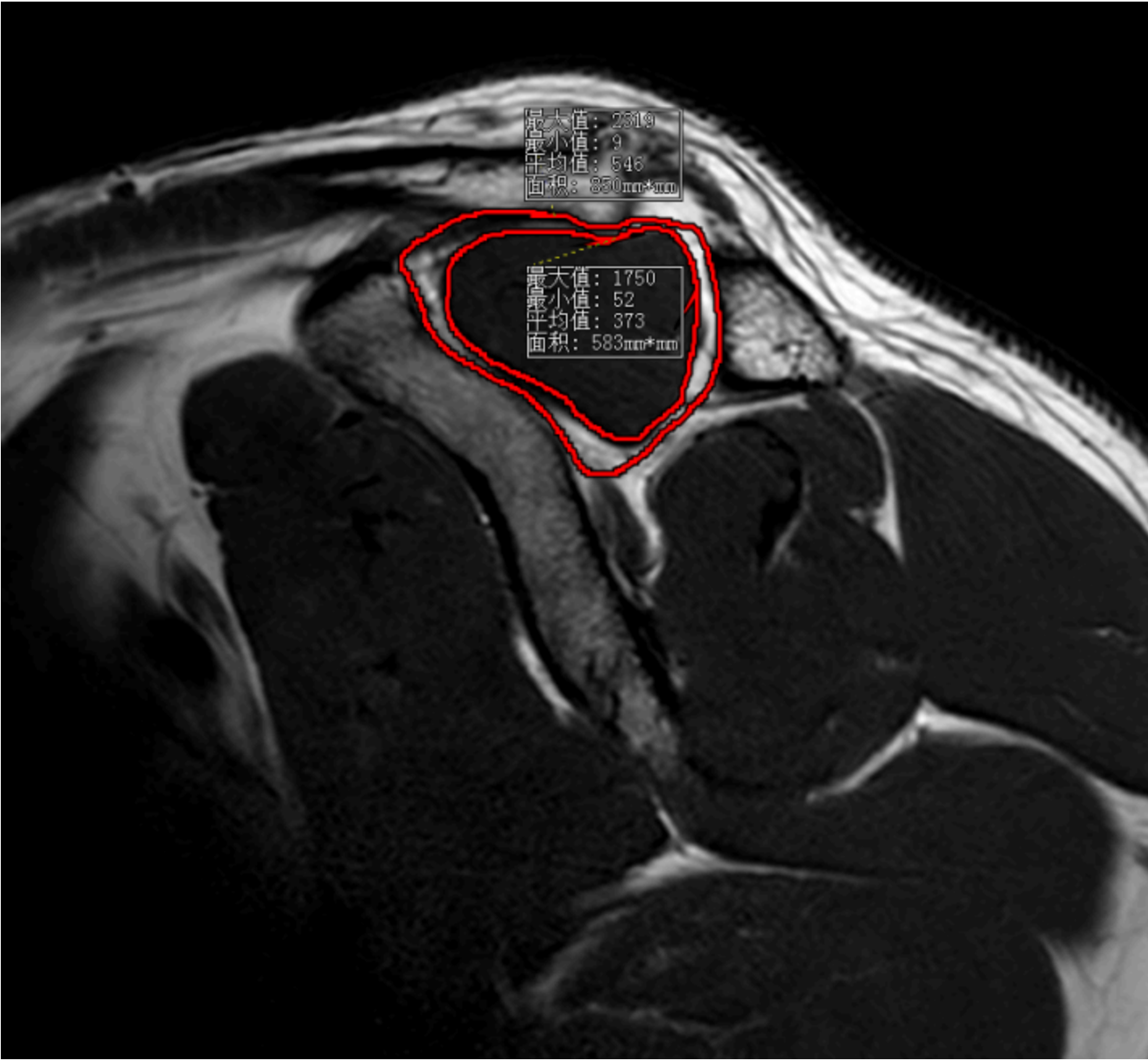


Figure 4

Measurement of the supraspinatus muscle occupation ratio on oblique sagittal magnetic resonance imaging.

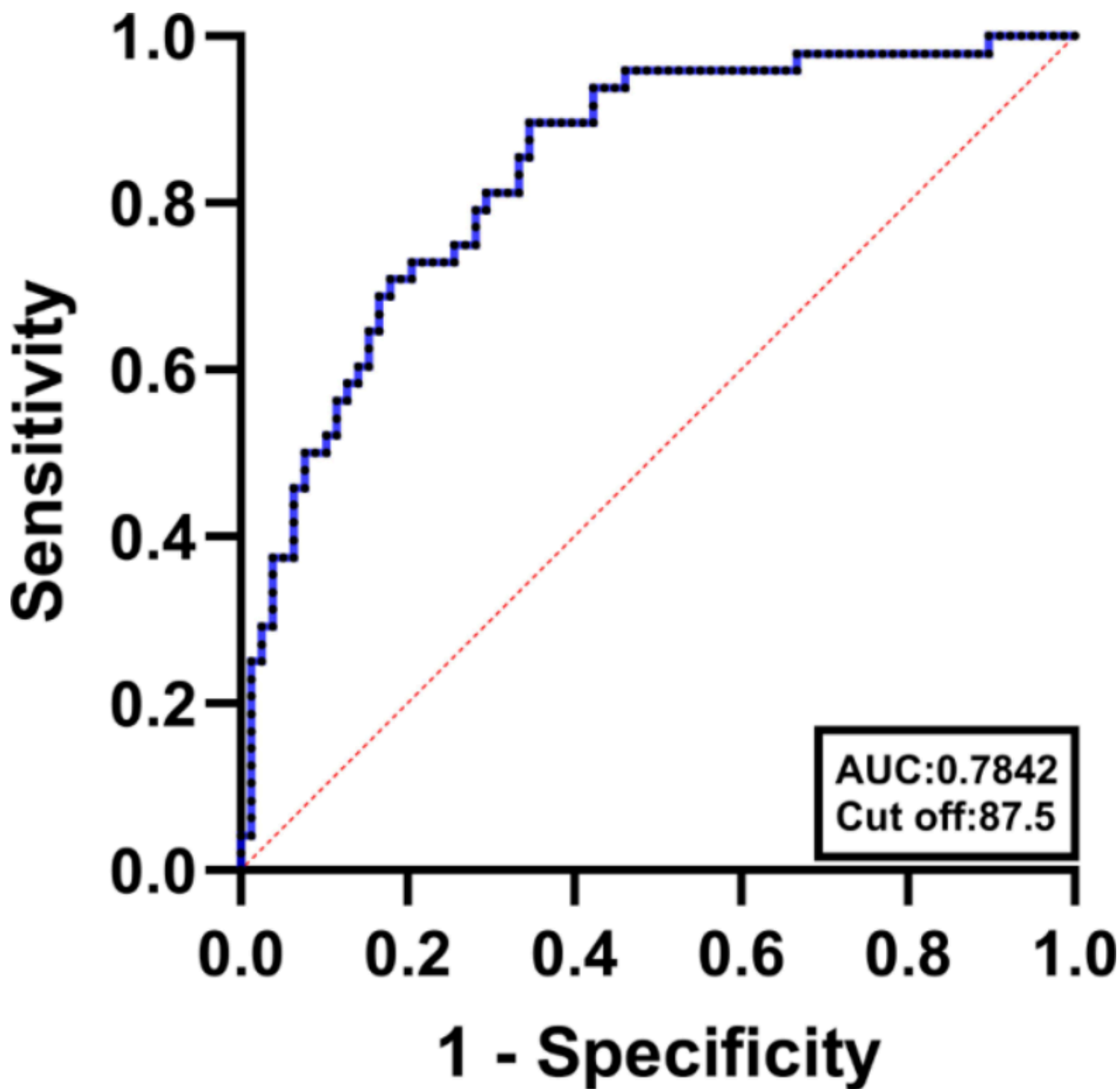


Figure 5

Receiver operating characteristic curve of proximal humeral Hounsfield unit values for unfavorable structural healing.

Supplementary Files

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