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ORIGINAL ARTICLE

The Effect of Acromial Morphology on the Functional Outcomes of Degenerative Rotator Cuff Tear Surgery

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Abstract

Purpose The aim of this study was to investigate how the critical shoulder angle (CSA) and acromion index (AI) affect the outcome of arthroscopic rotator cuff tear (RCT) repair.

Methods A total of 287 patients, who underwent arthroscopic surgery due to degenerative rotator cuff tear, were evaluated. The Constant Shoulder Score (CSS), Oxford Shoulder Score (OSS) and Visual Analogue Scale (VAS) were evaluated preoperatively and postoperatively. The AI and CSA were measured on true anteroposterior shoulder radiographs. The patients were separated into two groups according to their CSA and AI values (control group $\leq 38°$, increased CSA $> 38°$, and control group ≤ 0.7, increased AI > 0.7). The relationship between CSS, OSS and VAS was examined in all the groups.

Result The evaluation was made of a total of 287 patients with a mean age of 60.29 ± 8.55 years. The mean duration of follow-up of the patients was 34.00 ± 18.97 months (range 12–80 months). There was a statistically significant difference between the preoperative and postoperative clinical scores of the patients ($p < 0.05$). No relationship was determined between CSA, AI and CSS, OSS or VAS during follow-up ($p > 0.05$). The interobserver ICC for CSA and AI were determined to be 0.962 and 0.967, respectively (95% CI) indicating a high correlation ($p < 0.001$).

Conclusion CSA and AI do not affect functional outcomes in the postoperative period, so they are not significant at the time of degenerative arthroscopic rotator cuff repair decisions.

Keywords Acromial anatomy · Acromial index · Critical shoulder angle · Functional outcomes · Rotator cuff tear

Introduction

Rotator cuff tears (RCTs) are one of the most common diseases that require surgical treatment of the shoulder girdle. The incidence of RCT is anticipated to increase significantly as the population age increases [1, 2]. RCT pathogenesis is attributed to multiple factors, which are classified by some researchers as traumatic, intrinsic, and extrinsic causes. Recent studies have shown that acromial morphology is an important factor in RCT prevalence [3–5]. Due to the reported correlation between acromial morphology and the prevalence of RCTs in recently performed studies, intrinsic anatomic factors such as the critical shoulder angle (CSA) and the lateral extension of the acromion (AI) and have become considerable factors of affinity [2, 6]. The CSA described by Moor et al. has been indicated to be an important criterion in the presence of RCT [7]. The CSA is the integration of the measurement of the inclination of the lateral extension of the acromion and the glenoid [7]. Recent biomechanical studies have shown that repetitive active abduction movements of a large CSA create higher loading on the supraspinatus [8, 9].

Other authors have pointed out the lateral extension of the acromion (AI). The increase in lateral extension of the acromion causes degeneration of the supraspinatus due to a higher ascending force of the deltoid muscle. Many studies

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have shown that full-thickness RCT is associated with higher AI [10, 11].

Although there are studies in the literature that have informed a relation between CSA, AI and RCTs, the available information regarding the effect of acromial morphology on the outcome of RCT repair is relatively sparse. The aim of the present investigation was to evaluate the effect of CSA and AI on the outcomes of arthroscopic RCT repair. The hypothesis of the study was that increased CSA and AI would result in worse postoperative outcomes.

Methods

Patient Evaluation

The study included 287 patients who underwent arthroscopic rotator cuff surgery with a full-thickness repair involving the supraspinatus tendon, supported by physical examination between January 2010 and January 2017. Evaluations were done retrospectively. Patients with a complete range of motion of the shoulder joint, a full-thickness supraspinatus tear, and with a minimum follow-up period of 12 months were included in the study. Since degenerative rotator cuff tears were examined, patients older than 45 years were included in the study. Patients with inadequate radiography, previous surgical history, traumatic RCT history, degenerative joint disease, multiple tears, glenohumeral instability, trauma, or tumour, and infection history were not included in the study. Patients without a postoperative evaluation scale were also excluded from the study. This study was reviewed and approved by the Local Ethics Committee.

Preoperatively, digital true shoulder anteroposterior radiographs and MRI were evaluated of all patients (Figs. 1, 2). The AI and CSA were measured on true anteroposterior radiographs. The patients first were separated into two groups according to their CSA and AI values (control group $\leq 38°$, increased CSA $> 38°$, and control group ≤ 0.7, increased AI > 0.7) The functional, clinical preoperative, and postoperative evaluations of the

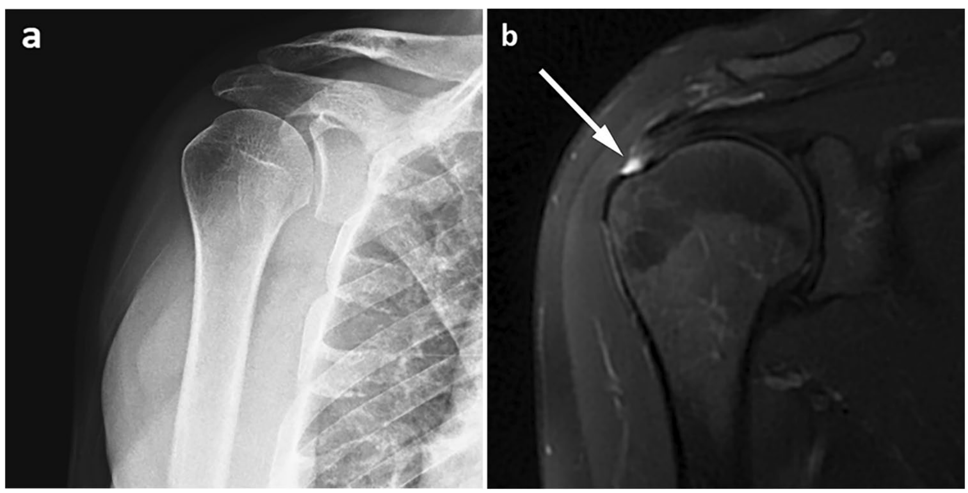

Fig. 1 **a**, **b** Preoperative radiography and MRI of a 48-year-old male patient. On proton density fat saturation image in the coronal plane, full-thickness supraspinatus tear (white arrow)

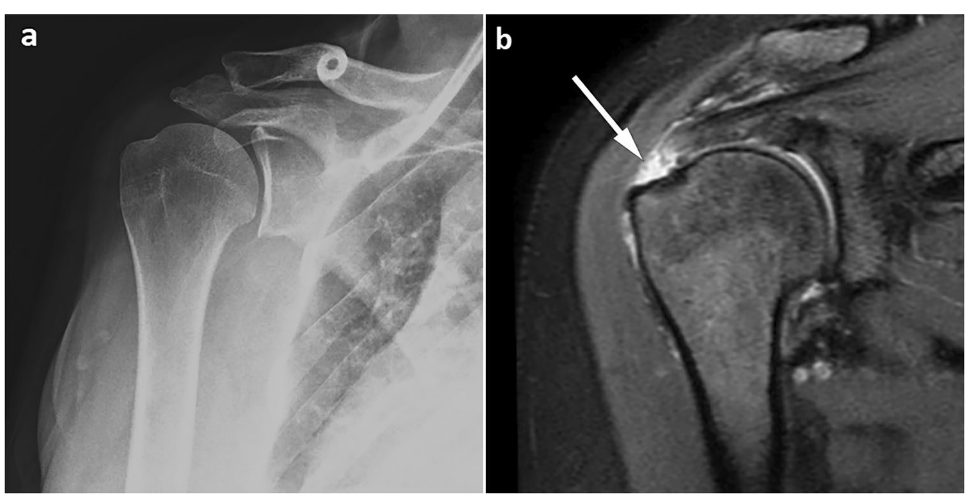

Fig. 2 **a**, **b** Preoperative radiography and MRI of a 55-year-old female patient. On proton density fat saturation image in the coronal plane, full-thickness supraspinatus tear (white arrow)

patients were made using the Constant Shoulder Score (CSS), Oxford Shoulder Score (OSS) and Visual Analog Score (VAS). At the preoperative and follow-up examinations of the patients, CSA and AI were compared between the control groups and other groups. The relationship between CSS, OSS and VAS was examined in the control groups and in all the other groups. The last evaluated result of each patient was included in the study.

Surgical Technique and Rehabilitation

All operations were performed under general anaesthesia and in the beach chair position. After entry from the standard posterior and anterior portals, the glenohumeral joint was first examined. Then the arthroscope was conducted into the subacromial space using the posterior portal. The subacromial bursa and under the surface of the acromion were debrided in all patients to provide better vision. To determine the mobility of the torn rotator cuff tendon, a tissue grasper was used, and an arthroscopic shaver was utilized to prepare the footprint on the greater tuberosity. If compression was present on the repaired rotator cuff in the subacromial space, acromioplasty was performed. While performing acromioplasty, the antero-inferior surface of the acromion was debrided from the medial joint border to the anterolateral corner. Resection was not performed from the lateral border of the acromion. All the operations were performed by an expert surgeon.

All patients underwent the same postoperative rehabilitation treatment. The arm was placed in an arm sling and passive movements were started on the first postoperative day. Strengthening exercises were initiated within 4–6 weeks postoperatively under the supervision of a physiotherapist.

Radiological Assessment

According to Moor et al. [7], the CSA is composed at the intersection of two lines, the first connecting the most lateral point of the acromion and the most lateral point of the inferior glenoid and representing the glenoid plane. Nyffeler et al. [11] stated that two distances are measured to calculate the acromion index (AI). The first extends from the glenoid plane to the acromion (GA) and the second from the glenoid plane to the lateral aspect of the humeral head (GH). The ratio of GA to GH represents the AI (Fig. 3).

In all the patients, true anteroposterior radiographs were taken with the forearm in a neutral position without the arm in abduction. The radiographs were accepted as valid when the shoulder joint space was seen with the anterior and posterior lips of the glenoid overlaying each other. The radiological parameters were measured as described in previous studies [7, 11]. The radiological measurements were evaluated on the true anteroposterior shoulder radiographs by 2 independent researchers, blinded to the results of each other. For the current study, the patients were separated into two groups according to their CSA and AI values (control group $\leq 38°$, increased CSA $> 38°$, and control group ≤ 0.7, increased AI > 0.7) [8, 11].

Statistical Analysis

To determine the size of the study sample, a power analysis was applied, and to be able to obtain a statistically significant difference with 0.80 power, 0.05 error margin, and 0.5 effect size, it was determined that a minimum size of 128 subjects was required. Data obtained in the study were analyzed statistically using IBM SPSS 20.0 software (IBM Corp., Armonk, NY, USA). Whether the data was normally distributed was evaluated using the Kolmogorov–Smirnov test. Numerical variables showing normal distribution were

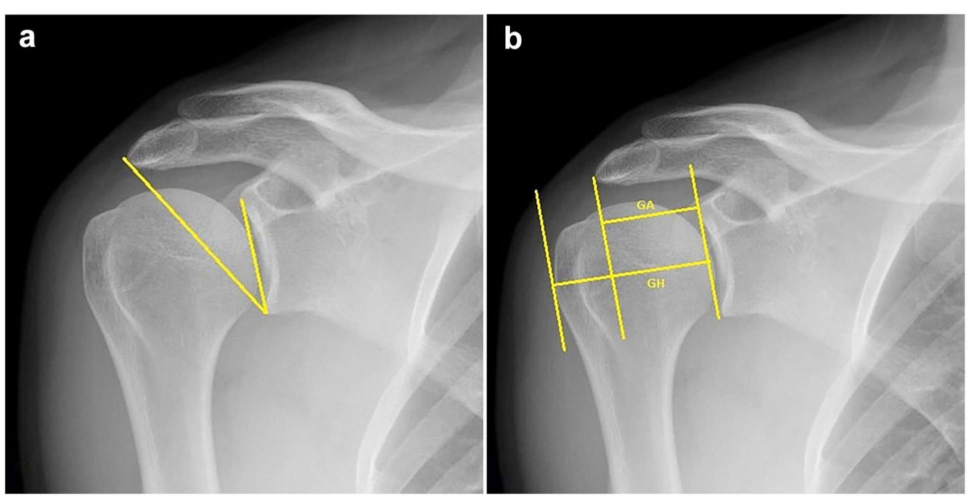

Fig. 3 **a** CSA was measured between a first line connecting the inferior border to the superior border of the glenoid fossa, and a second line connecting the inferior border of the glenoid to the most infero-lateral point of the acromion. **b** The acromion index (AI) was determined as the ratio of the distance from the glenoid plane to the acromion (GA) to the distance from the glenoid plane to the lateral aspect of the humeral head (GH)

stated as mean ± standard deviation values and those not showing normal distribution as median (minimum–maximum) values. Categorical variables were stated as number (*n*) and percentage (%). The difference between groups was determined with the Mann–Whitney *U* test for numerical variables not conforming to normal distribution. The difference between repeated measurements not showing normal distribution between groups was determined with the Wilcoxon test. Relationships between categorical variables were evaluated with Chi-square analysis. A value of $p < 0.05$ was accepted as statistically significant.

Interobserver agreement and reliability of numerical measurements were determined with the interclass correlation coefficient (ICC). ICC has a value between 0–1.0 and higher values indicate more reliability.

Results

The evaluation was made of a total of 287 patients, comprising 204 (71.08%) females and 83 (28.92%) males with a mean age of 60.29 ± 8.55 years. Right-side involvement was determined in 213 subjects (74.21%), and left-side in 74 subjects (25.79%). The mean duration of follow-up of the patients was 34.00 ± 18.97 months (range: 12–80 months). The mean CSA measured on the preoperative radiographs was 39.26° ± 4.39°, the mean AI value was 0.76 ± 0.07. The preoperative Constant and Oxford scores of the patients were 16.64 ± 7.85 and 33.99 ± 12.42, respectively. Postoperatively, the Oxford and Constant scores were 38.52 ± 9.68 and 77.34 ± 12.52, respectively. The VAS values of the patients were determined to be 9.37 ± 0.85 preoperatively and 2.60 ± 2.05 postoperatively. There was a statistically significant difference between the preoperative and postoperative clinical scores of the patients ($p < 0.05$).

There were 103 patients in the CSA control group (CSA ≤ 38°), and 184 patients in the increased CSA group (CSA > 38). The mean CSA value was 34.44 ± 2.51 in the control CSA group and 41.96 ± 2.50 in the increased CSA group. There was a statistically significant difference between the two groups ($p < 0.05$). No statistically significant difference was determined between the two groups in respect of age, gender, body mass index (BMI), operated side, follow-up duration, preoperative clinical scores, and VAS ($p > 0.05$). There were 91 patients in the AI control group (AI ≤ 0.7), and 196 patients in the increased AI group (AI > 0.7). The mean AI value was 0.66 ± 0.03 in the control AI group and 0.80 ± 0.05 in the increased AI group. There was a statistically significant difference between the two groups ($p < 0.05$). No statistically significant difference was determined between the two groups in respect of age, gender, body mass index (BMI), operated side, follow-up duration, preoperative clinical scores, and VAS ($p > 0.05$) (Table 1).

Table 1 Descriptive and clinical parameters at baseline

	Control CSA group (*n* = 103)	Increased CSA group (*n* = 184)	*p* value
Age ± SD	59.77 ± 7.59	60.59 ± 9.05	0.44
BMI ± SD	30.27 ± 2.44	30.05 ± 2.64	0.76
Side (R)	78	135	0.66
Gender (M/F)	25/78	58/126	0.19
CSA (°) ± SD	34.44 ± 2.51	41.96 ± 2.50	*p* < 0.001
CSS ± SD	33.60 ± 12.04	35.33 ± 12.46	0.12
OSS ± SD	15.91 ± 7.51	16.39 ± 7.95	0.24
VAS ± SD	9.43 ± 081	9.33 ± 0.87	0.37
Follow-up (months) ± SD	33.83 ± 18.52	34.10 ± 19.27	0.89
	Control AI group (*n* = 91)	Increased AI group (*n* = 196)	
Age ± SD	59.60 ± 8.18	60.61 ± 8.72	0.41
BMI ± SD	30.12 ± 2.43	30.13 ± 2.64	0.81
Side (R)	64	149	0.30
Gender (M/F)	25/66	58/138	0.71
AI ± SD	0.66 ± 0.03	0.80 ± 0.05	*p* < 0.001
CSS ± SD	34.36 ± 12.64	35.08 ± 19.82	0.75
OSS ± SD	15.93 ± 8.16	16.97 ± 7.69	0.08
VAS ± SD	9.49 ± 0.76	9.31 ± 0.88	0.09
Follow-up (months) ± SD	31.68 ± 16.88	35.08 ± 19.82	0.28

CSA critical shoulder angle, *AI* acromion index, *CSS* constant shoulder score, *OSS* oxford shoulder score, *VAS* visual analog scale, *SD* standard deviation, *BM* body mass index

In the control CSA group, the postoperative Oxford, Constant scores and VAS values were 38.05 ± 10.45, 76.55 ± 13.64, and 2.72 ± 2.20, respectively. In the increased CSA group, the postoperative Oxford, Constant scores and VAS values were 39.35 ± 9.15, 77.90 ± 11.59 and 2.46 ± 1.92 respectively. No relationship was determined between CSA and CSS, OSS or VAS during follow-up ($p > 0.05$). In the control AI group, the postoperative Oxford, Constant scores and VAS values were 38.08 ± 10.60, 76.73 ± 13.36, and 2.69 ± 2.27, respectively. In the increased AI group, the postoperative Oxford, Constant scores, and VAS values were 38.73 ± 9.24, 77.63 ± 12.13, and 2.56 ± 1.94, respectively. No relationship was determined between AI and CSS, OSS, or VAS during follow-up ($p > 0.05$) (Tables 2, 3). When the patient data was examined retrospectively, it was founded that postoperative stiffness occurred in 35 patients (%11.8). There were no intraoperative complications in the patients.

The interobserver ICC for CSA and AI were determined to be 0.962 and 0.967, respectively (95% CI) indicating a high correlation [12]. The agreement between the two observers in the CSA and AI values obtained from the measurements was found to be statistically significant ($p < 0.001$). The relationship between CSA and AI was also shown using the chi-square test (Table 4).

Table 2 Functional outcome scores based on CSA

	Control CSA group	Increased CSA group	*p* value
CSS ± SD	76.55 ± 13.64	77.90 ± 11.59	0.22
OSS ± SD	38.05 ± 10.45	39.35 ± 9.15	0.14
VAS ± SD	2.72 ± 2.20	2.46 ± 1.92	0.26

SA critical shoulder angle, *CSS* constant shoulder score, *OSS* oxford shoulder score, *VAS* visual analog scale, *SD* standard deviation

Table 3 Functional outcome scores based on AI

	Control AI group	Increased AI group	*p* value
CSS ± SD	76.73 ± 13.36	77.63 ± 12.13	0.54
OSS ± SD	38.08 ± 10.60	38.73 ± 9.24	0.73
VAS ± SD	2.69 ± 2.27	2.56 ± 1.94	0.84

AI acromion index, *CSS* constant shoulder score, *OSS* xford shoulder score, *VAS* visual analog scale, *SD* standard deviation

Table 4 Chi-square table

	AI ≤ 0.7	AI > 0.7	*p* value
CSA ≤ 38°	50	53	< 0.001
CSA > 38°	41	143	

CSA critical shoulder angle, *AI* acromion index

Discussion

The most important feature of this study is that it is one of the very few studies with a large sample size to have investigated the effect of preoperative CSA and AI on the functional outcomes of arthroscopic rotator cuff repairs. Contrary to the hypothesis, the study results did not demonstrate any important correlation between CSA, AI, and postoperative outcomes.

CSA was defined in 2013 by Moor et al. [7]. It was shown that there may be a high CSA in degenerative rotator cuff ruptures and a mean CSA of 38° was found in degenerative RCT patients. These findings were supported by Gerber et al.'s biomechanical experiments [8], which showed that a high CSA leads to overloading of the supraspinatus. Therefore, some authors have suggested that the clinical implications of the correlation between CSA and RCT might be important in surgery, stating that after cuff repair, surgical correction of CSA may reduce the cuff re-tear rate, and lateral decompression or lateral resection should be performed in RCT cases with a high CSA [13, 14]. In a clinical study by Gerber et al. the results of lateral acromioplasty were published [15]. The clinical results were evaluated retrospectively. The postoperative results were seen to be better than the preoperative values. It was also reported that insufficient correction could cause high rates of re-tear. However, in that study, there was no control group to which lateral acromioplasty was not applied, and the rotator cuff tears of the patients operated on were heterogeneous as cases with 2 or 3 tendon tears were included. In the current study, as there was no postoperative radiological imaging, the re-tear rate was not evaluated, but there was no significant difference in the clinical results between the increased CSA group and the control CSA group ($p > 0.05$).

In a recent biomechanical study, the glenohumeral joint was seen to be more stable in people with a small CSA [16]. As the force vector of the deltoid muscle decreases, the vertical shear force on the glenohumeral joint will decrease and in the load on the rotator cuff will also decrease. In a study by Gerber et al. individuals with a smaller CSA were reported to have better clinical outcomes after latissimus dorsi transfer [17]. They linked this to better glenohumeral stability. However, in that study, the cases evaluated were at least stage 3, with supraspinatus and infraspinatus tendon tears which could not be repaired and fatty infiltration. In the current study, only patients with full thickness supraspinatus tears were included. Although it was thought that patients with high CSA would have worse clinical outcomes, the effect of CSA on clinical results could not be demonstrated.

In a study by Garcia et al. it was reported that patients with high CSA had worse postoperative clinical results [18]. In contrast to that study, Kirsch et al. published the

24-month clinical results of 53 patients. These patients were separated into two groups as those with CSA < 38° and those with CSA ≥ 38°, and the postoperative clinical results were compared. No statistically significant relationship was determined between high CSA and clinical results [19]. Li et al. similarly retrospectively examined 90 patients in two groups of CSA < 38° and CSA ≥ 38°, and reported that high CSA did not affect the postoperative clinical outcomes [20]. In the current study, the 287 patients were separated into 2 groups and the clinical results were compared. No statistically significant difference was determined between the increased CSA group and the control CSA group in respect of the postoperative clinical results ($p > 0.05$).

In a study by Nyffeler et al. the AI was found to be significantly greater in full-thickness RC ruptures compared with a control group [11]. They stated that the lateral extension of the acromion influenced the results of the deltoid force vector. In this theory, the presence of a more lateral extension of the acromion is associated with an increased force component, and thus degenerative changes in the supraspinatus tendon and subacromial impingement support this theory [11]. Subsequently, the relationship between AI and RC rupture development was evaluated by several authors [21–23]. Scheiderer et al. reported a relationship between high AI values and rotator cuff re-tear after arthroscopic repair. However, no correlation was shown between the radiological measurements and the clinical results [24]. In the current study, no relationship was found between AI and the clinical results.

Zumstein et al. [25] declared a higher massive RCT recurrence rate after open repair in patients with larger AI, but did not detect any relation between AI and postoperative clinical outcomes. Ames et al. reported that a high AI increased instability and reduced clinical scores in the 24-month follow-up. The patients in that study with high AI had 2 or 3 tendon ruptures and several anchors were used for the repair [26]. Another clinical study informed that AI is not a predictor for recurring RC ruptures in the short-term after primary arthroscopic repair [27]. In a study of 147 patients by Lee et al. it was reported that the 24-month clinical results were not affected by high CSA and AI [28]. The focus of the current study was on isolated supraspinatus tears. The clinical results of the increased AI group were not seen to be worse than those of the control AI group.

A limitation of this study could be said to be the lack of postoperative imaging to reassess the integrity of the rotator cuff repair and acromial morphology. Previous studies in literature have shown high CSA and AI to be a reason for rotator cuff re-tear [18, 20, 24]. Acromial morphology can be re-evaluated with postoperative imaging and the clinical outcomes of patients can be compared. Several studies have indicated that repair integrity and clinical scores are inconsistent in the short term [24, 29]. Therefore, the relationship between postoperative clinical scores and repair integrity is controversial. Another limitation was that due to the retrospective nature of the study, there was a possibility of bias in the radiological measurements (the observers taking the measurements were independent of the study). The mean follow-up period of the patients was 33 months (range 12–80 months), and despite the mean follow-up period of longer than 24 months, the follow-up periods were heterogeneous because of the retrospective nature of the study, and this could have affected the clinical results.

Conclusion

Acromial morphological variations play a role in the pathogenesis of rotator cuff disease. CSA and AI are powerful radiographic determinants of rotator cuff pathology but do not appear to have a predictive effect on the outcome after arthroscopic repair of atraumatic, full-thickness tears.

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Authors' contribution MA: conceived and design the analysis, wrote the paper, performed the operations. ÇHB: performed the analysis, collected the data. YY: wrote the paper, collected the data, contributed data or analysis tools.

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Declarations

Conflict of interest All authors have no potential conflicts of interest, including financial interests, activities, relationships, and affiliations, to disclose.

Ethical approval We obtained ethical approval from the review board of Ankara University Faculty of Medicine (No. 15-958-17).

Informed consent Informed consent was obtained from all individual participants included in the study.

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