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Difference in vascular patterns between transosseous-equivalent and transosseous rotator cuff repair

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Background: Vascularity is the important factor of biologic healing of the repaired tissue. The purpose of this study was to clarify sequential vascular patterns of repaired rotator cuff by suture techniques.
Methods: We randomized 21 shoulders in 20 patients undergoing arthroscopic rotator cuff repair into 2 groups: transosseous-equivalent repair (TOE group, n = 10) and transosseous repair (TO group, n = 11). Blood flow in 4 regions inside the cuff (lateral articular, lateral bursal, medial articular, and medial bursal), in the knotless suture anchor in the TOE group, and in the bone tunnel in the TO group was measured using contrast-enhanced ultrasound at 1 month, 2 months, 3 months, and 6 months postoperatively.
Results: The sequential vascular pattern inside the repaired rotator cuff was different between groups. The blood flow in the lateral articular area at 1 month, 2 months, and 3 months ($P = .002$, .005, and .025) and that in the lateral bursal area at 2 months ($P = .031$) in the TO group were significantly greater than those in the TOE group postoperatively. Blood flow was significantly greater for the bone tunnels in the TO group than for the knotless suture anchor in the TOE group at 1 month and 2 months postoperatively ($P = .041$ and .009).
Conclusion: This study clarified that the sequential vascular pattern inside the repaired rotator cuff depends on the suture technique used. Bone tunnels through the footprint may contribute to biologic healing by increasing blood flow in the repaired rotator cuff.
Level of evidence: Basic Science Study; Anatomy

Keywords: Rotator cuff tear; contrast-enhanced ultrasound; vascularity; transosseous-equivalent repair; transosseous repair; biologic healing

Arthroscopic rotator cuff repair (ARCR) in a patient with a rotator cuff tear is one of the most common procedures in shoulder surgery. This procedure helps to reduce shoulder pain and to improve motion by facilitating the successful healing of a torn rotator cuff.[40] However, a recurrent tear often occurs after ARCR and can become a major problem. To prevent

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recurrent tears, several suture techniques for ARCR have been modified, focusing on improving the biomechanical properties at the repaired rotator cuff tendon, thereby increasing the primary fixation strength and providing a wide contact area.[14,31,38] Nevertheless, recurrent tears after rotator cuff repair remain a major concern.[2,15,20,34] The biologic environment around the repaired tendon should be considered in trying to achieve successful tendon-to-bone healing.

The vascularity inside the tissue is one of the most crucial factors for healing of damaged tissue.[25] The literature shows that the edges of the torn rotator cuff tendons are atrophic and avascular and that healing after surgical repair occurs through cellular proliferation and vascular ingrowth, which originate mainly from peribursal soft tissue and bone.[3,16,26,37] These studies indicate that vascularity inside the repaired tendon plays an important role in biologic healing at the tendon-to-bone insertion after rotator cuff repair.

Contrast-enhanced ultrasound (CEUS) is used to characterize the vascularity of the rotator cuff. Several authors have used CEUS and have reported enhanced blood flow patterns in rotator cuff tissues.[1,5,12,13,16,33] These authors have suggested that the blood flow inside the repaired rotator cuff tendon changes postoperatively and that these changes may affect the healing of the tendon-to-bone insertion. However, no studies have compared the effect of different suture techniques on blood flow inside the repaired rotator cuff.

We hypothesized that the sequential vascular pattern inside the repaired rotator cuff would differ between suture techniques and that bone tunnels through the footprint would increase the blood flow inside the repaired rotator cuff. The purpose of this study was to use CEUS to compare the sequential vascular patterns of rotator cuffs repaired by 2 suture techniques. The second objective was to investigate whether the blood flow in the repaired rotator cuffs using the transosseous rotator cuff repair would be superior to that using the transosseous-equivalent rotator cuff repair.

Methods

Patient enrollment

Between September 2013 and March 2015, 47 patients were eligible if they were scheduled for ARCR. Surgery was performed by 1 of 2 surgeons (A.U. or T.F.). A power analysis was performed to determine the sample size for each group. Assumptions about primary outcome values and variance were based on a previous study by Funakoshi et al.[13] The sample size was determined on the basis of the mean ± standard deviation of preoperative and postoperative vascularity in the peritendinous tissue in patients with ARCR. Our power analysis indicated that 9 patient samples in each group were required to detect this effect size with a power of 80% and α of .05. To account for possible loss to follow-up, 25 patients were enrolled in the study.

The criteria for inclusion in this study were the presence of a superior chronic full-thickness supraspinatus or infraspinatus tendon tear and an intact insertion of the subscapularis and teres minor tendons. The rotator cuff tear was classified as a small or medium full-thickness tear according to Cofield's classification.[7] Patients with a long head of biceps tendon disorder, history of tobacco use, or cardiovascular disease were included. Patients with a traumatic rotator cuff tear, isolated subscapularis or teres minor tear, large or massive rotator cuff tear, previous shoulder operation, or obvious glenohumeral osteoarthritis on preoperative radiographs were excluded.

The patients were randomized into 2 groups: 11 shoulders in 10 patients in the transosseous-equivalent rotator cuff repair (TOE) group and 14 shoulders in 14 patients in the transosseous rotator cuff repair (TO) group. Informed consent to participate in the study was obtained from each patient. The tear pattern, which agreed with the inclusion criteria, was confirmed at the time of arthroscopy. One patient in the TOE group and 1 patient in the TO group were lost to follow-up, 1 patient in the TO group was unable to undergo postoperative magnetic resonance imaging (MRI), and 1 patient in the TO group had inadequate ultrasound data, leaving 10 shoulders in the TOE group and 11 shoulders in the TO group in the study (Fig. 1).

All patients had chronic shoulder pain that had been treated preoperatively with medication, subacromial injection, and/or physical therapy for a minimum of 3 months. One patient in the TOE group and 1 patient in the TO group were smokers. No patient in the TOE group and 2 patients in the TO group had cardiovascular disease.

All patients underwent a physical examination before the operation and 3 and 6 months postoperatively. Three clinically based outcome scores were used. All patients were assessed preoperatively and postoperatively using the 35-point University of California–Los Angeles shoulder scoring scale,[10] the 100-point Japanese Orthopaedic Association score,[21] and the 100-point Constant-Murley score.[8,18]

The preoperative radiographic evaluation involved anterosuperior and scapular lateral fluoroscopically controlled views. There was no obvious glenohumeral osteoarthritis in this series. Computed tomography arthrography and MRI were performed preoperatively in all patients to confirm the full-thickness rotator cuff tear. In the current study, there were 7 small tears and 14 medium tears.

The pattern of rotator cuff tear was assessed according to the size criterion, under direct visualization during the operation using the arthroscope in the lateral portal. The tear area anteroposterior diameter and mediolateral diameter were measured and recorded in millimeters, as previously described.[17,22,23,41]

Surgical technique

All patients underwent shoulder arthroscopy in the beach chair position under general anesthesia and a preoperative interscalene block. A 30° arthroscope was used for visualization. Standard diagnostic arthroscopy was used to assess all intra-articular structures and the rotator cuff tendon through the anterior and posterior portals; this was followed by bursectomy and acromioplasty using Ellman's methods.[9]

After bursectomy of the subacromial space and débridement around the ruptured tendon, the footprint was identified on the greater tuberosity and abraded with a shaver until cancellous bone was exposed. One suture anchor (5.5-mm HEALIX ADVANCE BR Anchor; DePuy Synthes Mitek, Raynham, MA, USA) was placed at the medial edge of the greater tuberosity footprint at 45° to the footprint surface, and 6 threads were passed through the ruptured tendon without tying. Then 2 knotless suture anchors (VERSALOK; DePuy Synthes Mitek) were used to fix the threads at the lateral aspect of the greater tuberosity in the TOE group.[31,32] Each knotless suture

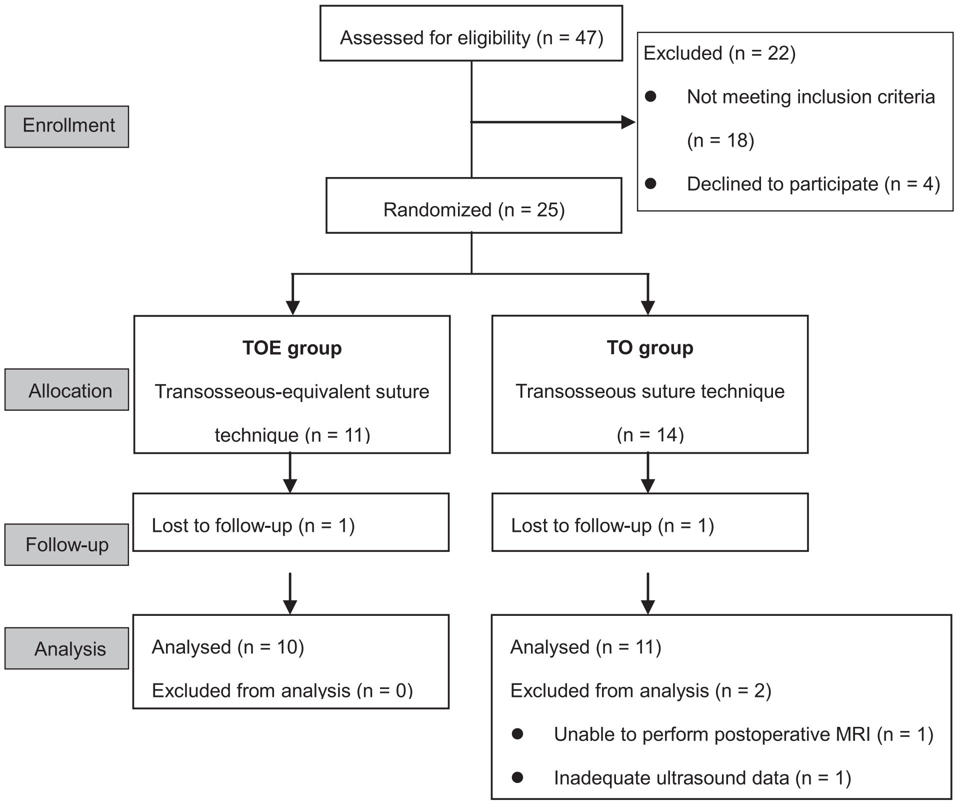

Figure 1 A Consolidated Standards of Reporting Trials (CONSORT) flow diagram. *TOE*, transosseous-equivalent rotator cuff repair; *TO*, transosseous rotator cuff repair; *MRI*, magnetic resonance imaging.

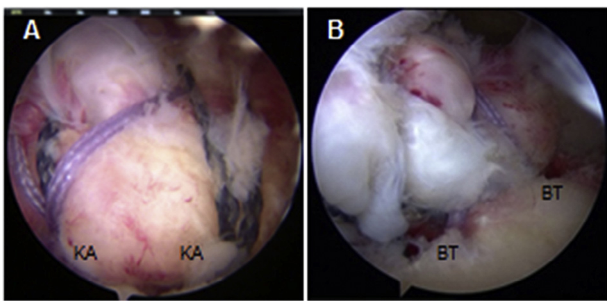

Figure 2 Representative arthroscopic images of the transosseous-equivalent rotator cuff repair (**A**) and the transosseous rotator cuff repair (**B**). (**A**) Threads, which were passed through the ruptured tendon, were fixed to the lateral aspect of the greater tuberosity using 2 knotless suture anchors. (**B**) Two tunnels were created from the lateral footprint to the lateral cortex, and threads were then pulled out through the tunnels and tied below the greater tuberosity. *KA*, knotless suture anchor; *BT*, bone tunnel.

anchor was placed 10 mm distal to the lateral edge of the footprint, and the distance between each anchor was ~10 mm (Fig. 2, *A*). In the TO group, 2 bone tunnels were created from the lateral edge of the footprint to the lateral cortex below the greater tuberosity with the use of a giant needle (2.2 mm in diameter and 240 mm in length; Mutoh, Sapporo, Japan). The distance between each bone tunnel on the footprint was ~10 mm. The threads were pulled out through the tunnels and tied below the greater tuberosity as a lateral transosseous fixation (Fig. 2, *B*).[14,35,39]

Postoperative rehabilitation was performed using the same protocol in both groups. An abduction pillow was used for 6 weeks postoperatively. Under the guidance of a physiotherapist, the patients completed a systematic rehabilitation program comprising passive exercises starting 3 days postoperatively. Active elevation of the shoulder from the adducted position in a sitting position was allowed 8 weeks postoperatively. Heavy work and sports were allowed 6 months postoperatively. At 3 and 6 months postoperatively, all patients underwent a physical examination and an MRI scan.

Contrast-enhanced ultrasound

The patients underwent CEUS at 1 month, 2 months, 3 months, and 6 months postoperatively. All 84 examinations were performed by 1 certified sonographer (T.H.). Ultrasound images were corrected using an ultrasound unit (Aplio 500; Toshiba Medical System Corp, Tochigi, Japan) with a 7.5 MHz center frequency linear transducer (PLT-740AT). All scans were performed in shoulder extension to optimize the visualization of the supraspinatus tendon–bone junction, as previously described.[12,13] B-mode images were obtained initially to confirm optimum visualization of the rotator cuff in the oblique coronal plane. The proximal anchor hole and the distal knotless anchor in the TOE group or the bone tunnels in the TO group were focused to identify the same imaging plane in each patient. An intravenous catheter was placed in the contralateral forearm of the repaired rotator cuff. The patient underwent CEUS with the intravenous ultrasound contrast agent Sonazoid (Daiichi Sankyo, Tokyo, Japan), which comprises perflubutane microbubbles and lipid shells. This was injected intravenously at a concentration of 0.015 mL/kg,

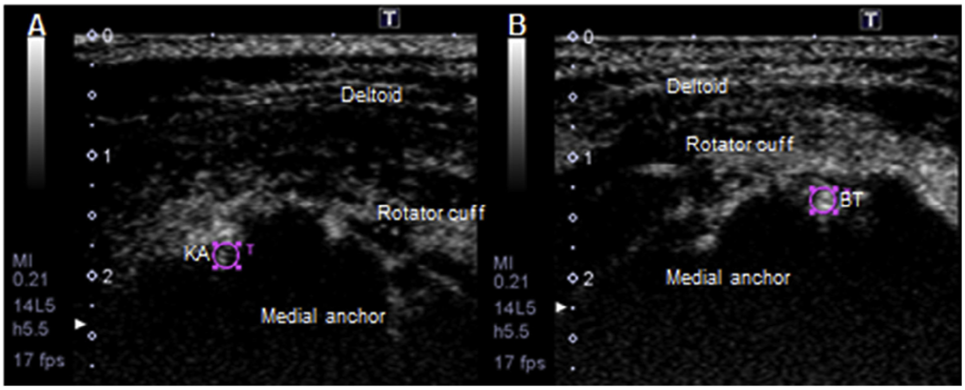

Figure 3 Contrast-enhanced ultrasound (CEUS) images of the repaired rotator cuff at 2 months postoperatively. (**A**) CEUS image of the right shoulder in the TOE group. (**B**) CEUS image of the left shoulder in the TO group. *KA*, knotless suture anchor; *BT*, bone tunnel.

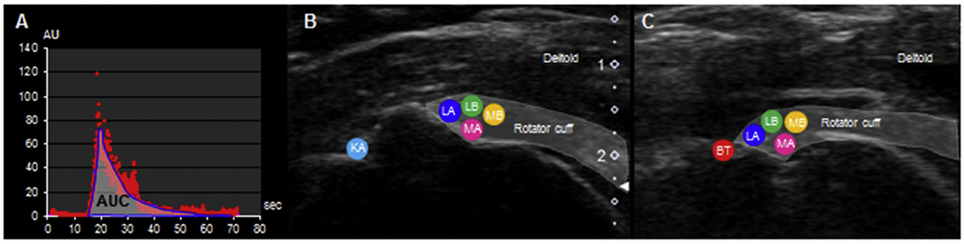

Figure 4 Ultrasonography of the repaired rotator cuff. (**A**) Time-intensity curve for the representative region of interest (ROI) imaged using contrast-enhanced ultrasound. *AU*, acoustic unit; *AUC*, area under the time-intensity curve. (**B**) Five ROIs are shown in the TOE group. (**C**) Five ROIs are shown in the TO group. The ROIs are the lateral articular tendon (*LA, blue dot*), lateral bursal tendon (*LB, green dot*), medial articular tendon (*MA, pink dot*), medial bursal tendon (*MB, orange dot*), knotless suture anchor (*KA, cyan dot*), and bone tunnel (*BT, red dot*). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

followed by a 10-mL saline flush. The CEUS images were recorded digitally for 70 seconds after the contrast medium injection (Fig. 3).

Vascularity of the repaired rotator cuff

Time-intensity curves based on continuous raw data were obtained using time curve analysis software included in the ultrasound unit (Fig. 4, *A*). The regions of interest were evaluated as circles (2.94 mm^2) in 4 areas inside the cuff (lateral articular [LA], lateral bursal [LB], medial articular [MA], and medial bursal [MB]), in the knotless suture anchor in the TOE group, and in the bone tunnels in the TO group (Fig. 4, *B* and *C*). Normalized data were obtained for each area relative to a baseline by using an average from the first 280 frames (about 18 seconds). The values for the area under the time-intensity curve (AUC) were calculated using an original program (IGModelv3.7-gfor2007.xls; Toshiba Medical Systems Corp) and were recorded as acoustic units for statistical analysis. All analyses were performed in a blinded fashion and not in real time by a single investigator (A.U.).

Statistical analysis

All statistical analyses were performed using Excel 2010 (Microsoft Corp, Redmond, WA, USA). Paired *t*-tests were used to compare preoperative and postoperative functional scores and range of motion in both groups. Unpaired *t*-tests were used to compare age, sex, side, smoking, cardiovascular disease, tear size, functional score, range of motion, and the mean AUCs of each area inside the repaired rotator cuff (LA, LB, MA, and MB) and to compare the mean AUCs for the knotless suture anchor in the TOE group with those for the bone tunnels in the TO group. A probability of < .05 was considered significant.

Results

Demographic data and clinical outcome

The patients' demographic data are shown in Table I. There were no significant differences in age, sex, smoking, and cardiovascular disease between groups. The mean tear area was measured during the operation. The anteroposterior diameter and mediolateral diameter did not differ significantly between groups.

The clinical scores and the shoulder range of motion are shown in Table II. There was a significant improvement in all 3 clinical scores from preoperatively to 6 months postoperatively in both groups ($P < .001$). There were no significant differences in all 3 clinical scores and shoulder range of motion between groups before surgery and 6 months postoperatively (Table II). For measures of shoulder range of motion, there was a significant improvement in forward flexion from preoperatively to 6 months postoperatively in both the TOE

Table I Participant demographics

	TOE	TO	*P* value
Patients	10	11	
Age, years	67.6 ± 3.9	65.5 ± 11.6	.57
Sex, male/female	6/4	9/2	.56
Side, right/left	4/6	4/7	.87
Smoking	1	1	1
Cardiovascular disease	0	2	.15
Tear size			
AP diameter, mm	15.2 ± 5.8	15.2 ± 6.7	.99
ML diameter, mm	16.0 ± 5.7	14.2 ± 3.3	.40

TOE, transosseous-equivalent repair; *TO*, transosseous repair; *AP*, anteroposterior; *ML*, mediolateral.
Data are expressed as number or mean ± standard deviation.

and TO groups (P = .038 and .019, respectively). There was no significant improvement in external rotation from preoperatively to 6 months postoperatively in either the TOE or TO group (P = .056 and .131, respectively). MRI for all patients showed no obvious rerupture of the rotator cuff at 3 and 6 months postoperatively.

Postoperative vascular patterns inside the repaired cuff

No patient experienced any adverse event from the intravenous contrast agent used. In the TOE group, the mean AUC for the LA area in the repaired rotator cuff increased at 2 months and then decreased at 6 months postoperatively. The mean AUC for the LB and MB areas increased at 3 months and then decreased at 6 months postoperatively (Fig. 5, *A*). The mean AUC for the MA area increased gradually to 6 months postoperatively.

Changes in the mean AUC for each area were greater in the TO group compared with the TOE group. The mean AUCs for the distal areas of the repaired cuff (LA and LB) and the MB area increased at 2 months and then decreased at 6 months postoperatively (Fig. 5, *B*). The mean AUC for the MA area increased gradually to 3 months and then decreased at 6 months postoperatively.

The mean AUCs for the knotless suture anchors in the group showed no obvious alterations from 1 month to 6 months postoperatively (Fig. 5, *C*). By contrast, the mean AUCs for the bone tunnels in the TO group increased at 2 months postoperatively and decreased at 6 months postoperatively. The mean AUCs at 1 month and 2 months postoperatively were significantly greater for the bone tunnels in the TO group compared with those for the knotless suture anchors in the TOE group (P = .041 and .009).

Differences of blood flow between suture techniques

The AUCs for each area inside the repaired rotator cuff were compared between groups at each postoperative time point (Table III). At 1 month, the mean AUC for the LA area was significantly higher in the TO group than in the TOE group (P = .002). There were no significant differences between the groups in mean AUCs for other areas (LB, MA, and MB). At 2 months, the mean AUCs for lateral areas (LA and LB) were significantly higher in the TO group than in the TOE group (LA, P = .005; LB, P = .031). By contrast, there were no significant differences between groups in the mean AUCs of medial areas (MA and MB). At 3 months, the mean AUC for the LA area was significantly higher in the TO group than in the TOE group (P = .025). There were no significant differences between groups for other areas. At 6 months, there were no significant differences between groups in the mean AUCs for all areas of the repaired cuffs.

Discussion

This study shows that the sequential vascular pattern inside the repaired rotator cuff differs according to the suture technique used. In the current results, the blood flow in most areas in the TOE and TO groups increased at 2 to 3 months postoperatively but that in the MA area in the TOE group gradually increased to 6 months postoperatively. Alterations of vascular patterns inside repaired rotator cuffs were more pronounced in lateral and articular areas (LA, LB, and MA) in the TO group. These results indicate that the postoperative vascular

Table II Clinical score and shoulder range of motion

	Preoperative			Postoperative at 6 months		
	TOE	TO	*P* value	TOE	TO	*P* value
UCLA score	13.7 ± 4.1	14.8 ± 6.6	.65	32.8 ± 1.2	33.5 ± 1.4	.36
JOA score	61.4 ± 13.8	63.0 ± 14.1	.80	89.5 ± 3.6	91.5 ± 4.1	.27
Constant score	43.3 ± 16.9	49.8 ± 18.6	.41	81.1 ± 3.6	78.9 ± 6.1	.48
Range of motion						
Forward flexion, degrees	115.6 ± 38.9	115.9 ± 46.6	.81	147.5 ± 10.4	149.1 ± 16.4	.81
External rotation, degrees	27.5 ± 12.7	33.6 ± 11.4	.34	36.9 ± 6.5	38.6 ± 8.7	.64

TOE, transosseous-equivalent repair; *TO*, transosseous repair; *UCLA*, University of California–Los Angeles; *JOA*, Japanese Orthopaedic Association.
Data are expressed as mean ± standard deviation.

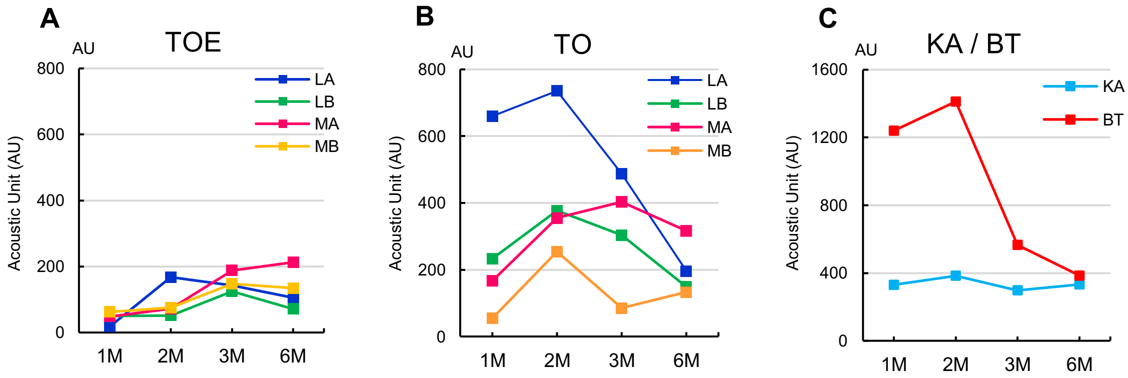

Figure 5 Sequential vascular patterns in the repaired rotator cuff tendon in both groups. (**A**) Sequential vascular pattern in the transosseous-equivalent rotator cuff repair (*TOE*) group. (**B**) Sequential vascular pattern in the transosseous rotator cuff repair (*TO*) group. (**C**) Sequential vascular patterns in the knotless suture anchor (*KA*) area in the TOE group and the bone tunnel (*BT*) area in the TO group. *LA*, lateral articular; *LB*, lateral bursal; *MA*, medial articular; *MB*, medial bursal.

Table III Comparison of postoperative blood flow between the TOE and TO groups at 1, 2, 3, and 6 months postoperatively

		1 month		2 months		3 months		6 months	
		Acoustic unit	*P* value	Acoustic unit	*P* value	Acoustic unit	*P* value	Acoustic unit	*P* value
LA	TOE	18.1 ± 24.1	.002*	167.5 ± 205.7	.005*	142.9 ± 171.4	.025*	105.8 ± 135.3	.250
	TO	659.6 ± 805.1		735.4 ± 531.0		487.2 ± 415.9		196.5 ± 203.6	
LB	TOE	50.2 ± 45.4	.082	51.3 ± 84.1	.031*	124.1 ± 119.4	.131	70.9 ± 75.2	.415
	TO	223.7 ± 294.9		377.1 ± 433.4		304.0 ± 341.4		149.1 ± 287.9	
MA	TOE	48.7 ± 105.3	.220	72.1 ± 90.7	.109	187.5 ± 281.1	.270	212.6 ± 370.4	.530
	TO	167.4 ± 278.1		355.2 ± 523.3		403.5 ± 537.5		316.4 ± 372.1	
MB	TOE	62.4 ± 86.2	.828	75.0 ± 149.8	.169	147.2 ± 199.1	.414	134.1 ± 166.3	.993
	TO	55.2 ± 60.7		254.2 ± 368.9		86.1 ± 133.0		133.2 ± 262.5	

TOE, transosseous-equivalent repair; *TO*, transosseous repair; *LA*, lateral articular; *LB*, lateral bursal; *MA*, medial articular; *MB*, medial bursal.
Results are expressed as mean ± standard deviation.
* Statistical significance between TOE and TO groups ($P < .05$).

pattern differs according to the suture technique. Comparing the blood flow in each area inside the repaired rotator cuff between both groups, the blood flow in the LA area at 1 month, 2 months, and 3 months and that in the LB area at 2 months in the TO group were significantly higher than those in the TOE group postoperatively. On the other hand, the blood flow through bone tunnels in the TO group was correspondingly higher than that through the knotless suture anchors in the TOE group at 1 month and 2 months postoperatively. These results suggest that the bone tunnels on the footprint used in the transosseous suture technique provide more blood flow inside the repaired rotator cuff compared with the knotless suture anchors used in the transosseous-equivalent suture technique.

Several authors have reported on vascular patterns inside the repaired rotator cuff visualized using CEUS.[1,5,12,13,16,33] Funakoshi et al observed marked alterations in the microvascular pattern inside the torn cuff at 3-month postoperative intervals.[13] Fealy et al noted that the robust vascular response in the repaired rotator cuff tendon decreased with time after the operation.[11] To our knowledge, our randomized study is the first to compare the sequential vascular patterns inside the repaired rotator cuff between different suture techniques. The 2 suture techniques in our study differed in the fixation method of threads passed through the ruptured tendon. In the TOE group, knotless suture anchors were used at the lateral aspect of the greater tuberosity; in the TO group, bone tunnels were created on the footprint and the threads were pulled out below the greater tuberosity. The vascular patterns showed that the changes in blood flow in the LA tendon correspond to the patterns made by the knotless suture anchors (TOE group) and bone tunnels on the footprint (TO group). The bone tunnels were closer to the margin of the repaired rotator cuff compared with the knotless suture anchors. Therefore, the blood flow inside the repaired rotator cuff may have infiltrated from the LA area, and the bone tunnels may have provided greater blood flow to the lateral and articular areas in the TO group.

Recurrent tears appear to occur more frequently in the first 3 months after rotator cuff repair.[28,30] In the study by Miller et al, recurrent tears that occurred in the early postoperative periods were associated with inferior clinical outcomes, and no recurrent tears occurred after 6 months.[30] Kluger et al reported that the healed tendon, which was evaluated at 6 months postoperatively, appeared to predict the clinical outcomes and that the healing during the initial 3 months had long-term implications for maintenance of cuff integrity and clinical outcomes.[28] Hypervascularity seems to accelerate the healing process in tendons, and the rotator cuff tendon is poorly vascularized.[25] This suggests that an increase in blood flow inside the repaired rotator cuff during the first 3 postoperative months may help accelerate biologic healing of the tendon-to-bone interface. Therefore, the transosseous suture technique, which was associated with greater blood flow inside the repaired rotator cuff in the first 3 postoperative months, may provide sufficient blood flow to enhance the biologic remodeling of the tendon-to-bone interface.

Bone marrow mesenchymal stem cells (BMSCs) have been reported to play a role in the healing process of tendon tissues.[4,6,19,24,29] However, it is controversial whether these cells can improve the biologic healing inside repaired rotator cuffs. Gulotta et al studied the healing of the tendon-to-bone insertion by adding BMSCs in a rat supraspinatus repair model. However, they found that the application of BMSCs did not improve healing at the early time points. By contrast, using bone marrow chimeric rats that expressed green fluorescent protein, Kida et al found that BMSCs passed through holes on the footprint, infiltrated the repaired tendon, and promoted postoperative rotator cuff healing.[27] Correspondingly, Taniguchi et al investigated the effects of bone marrow stimulation on cuff repair integrity after an arthroscopic surface-holding repair in the patients with chronic rotator cuff tear.[36] They found that marrow stimulation at the footprint during ARCR increased the integrity of the repaired rotator cuff, especially for large and massive rotator cuff tears. Bone marrow contains bone marrow–derived cells and several growth factors, which accelerate biologic healing in the repaired rotator cuff. On the basis of these results, bone tunnels on the footprint may contribute to biologic healing by increasing blood flow and the delivery of bone marrow–derived cells and growth factors, which may infiltrate the repaired rotator cuff from the bone tunnels.

There are several limitations to this study. First, this study evaluated the blood flow in repaired rotator cuffs only in patients with a small or medium tear. Previous studies have reported higher rates of recurrent tears for large to massive tears compared with small to medium tears.[2,15,20,34,35] To standardize the patients' background, clinical results, and postoperative cuff integrity, the current study included only patients with a small or medium tear. Second, we used VERSALOK, which is not a cannulated design, for the knotless suture anchors in the TOE group. Cannulation of the anchors may provide greater blood flow from bone marrow. However, the bone tunnels were closer to the repaired rotator cuff compared with the knotless suture anchor at the lateral aspect of the greater tuberosity. Therefore, it is reasonable to suggest that bone tunnels on the footprint would provide greater blood flow. Third, we evaluated the blood flow in the repaired rotator cuff in only a single plane because 3-dimensional analysis of blood flow inside the rotator cuff could not be investigated using CEUS. Therefore, we measured sequential alterations in vascularity in the repaired rotator cuff from the proximal anchor to the bone tunnels or the knotless suture anchors in a way that allowed repeated scans to be performed in the same position. Finally, the relationship between blood flow and rotator cuff healing has not been elucidated directly. Further studies are needed to clarify the role of blood flow in the healing process in repaired rotator cuffs.

Conclusion

This study clarifies that the sequential vascular pattern inside the repaired rotator cuff differs according to the suture technique used. The transosseous suture technique provided greater blood supply through bone tunnels inside the repaired cuff. Although additional studies are needed to confirm these findings, the current results suggest that bone tunnels on the footprint can contribute to biologic healing by increasing the blood flow inside the repaired rotator cuff.

Disclaimer

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