CURRENT CONCEPTS REVIEW

Factors Affecting Rotator Cuff Healing

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- Several studies have noted that increasing age is a significant factor for diminished rotator cuff healing, while biomechanical studies have suggested the reason for this may be an inferior healing environment in older patients.
- Larger tears and fatty infiltration or atrophy negatively affect rotator cuff healing.
- Arthroscopic rotator cuff repair, double-row repairs, performing a concomitant acromioplasty, and the use of platelet-rich plasma (PRP) do not demonstrate an improvement in structural healing over mini-open rotator cuff repairs, single-row repairs, not performing an acromioplasty, or not using PRP.
- There is conflicting evidence to support postoperative rehabilitation protocols using early motion over immobilization following rotator cuff repair.

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Rotator cuff tears affect a substantial number of patients as they age and are a major cause of pain and dysfunction with overhead activities. In patients with persistently symptomatic rotator cuff tears despite conservative treatment, surgery may be indicated to repair the torn tendon, with the goal of eliminating pain and restoring function. Healing of the rotator cuff repair is thought to improve functional outcomes, and the factors associated with this are multifactorial in nature. Studies have evaluated the healing process from the molecular and cellular level[1-3], in biomechanical studies[4-7], and in various clinical scenarios[8-10]. The body of literature examining the various factors that can influence the results following rotator cuff repair is extensive, and was recently evaluated with a clinical practice guideline review[11]. However, the authors of the clinical practice guideline did not specifically review the factors that can impact healing of the rotator cuff tendon to bone. The aim of the present article was to review the current evidence related specifically to the healing of full-thickness rotator cuff tears following repair, evaluating the role of surgical and patient-based factors that may impact the healing process.

How Is Healing Determined?

Many studies on rotator cuff repairs base outcomes on patient function; however, functional improvement does not always coincide with healing. Only studies documenting healing utilizing advanced postoperative imaging findings were used in this review. Healing, for the purposes of this review, indicates a continuous layer of tissue from the rotator cuff muscle belly to the insertion on the greater tuberosity. The sensitivity and specificity of magnetic resonance imaging (MRI)[12-14], ultrasound[14-17], and computed tomography (CT) arthrography[18] are reported in Table I. While there are known limitations of each imaging modality compared with arthroscopic visualization[19], advanced imaging has been considered a reasonable noninvasive alternative to assess the status of the rotator cuff after repair[13,17]. The term *retear* is used throughout the literature when rotator cuff healing is assessed, but most studies do not

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TABLE I Advanced Imaging of the Rotator Cuff

	Rotator Cuff Tear		Detection of Defects After Rotator Cuff Repair	
Study*	Sensitivity	Specificity	Sensitivity	Specificity
MRI				
de Jesus et al.[12] (2009)	86%	90%		
Dinnes et al.[14] (2003)	89%	93%		
Motamedi et al.[13] (2002)			91%	25%
MRA				
Dinnes et al.[14] (2003)	95%	93%		
Ultrasound				
Teefey et al.[15,16] (2000 and 2009)	100%	85%		
Prickett et al.[17] (2003)			91%	86%
Dinnes et al.[14] (2003)	87%	96%		
CT arthrography				
Charousset et al.[18] (2005)	99%	100%		

*MRI = magnetic resonance imaging, MRA = magnetic resonance arthrography, and CT = computed tomography.

specifically document healing followed by recurrent tears. Therefore, in this article, we refrain from using the term *retear.*

Does Healing Affect Outcomes?

Shoulder function can be measured by pain, outcome scores, range of motion, and strength. Several studies[9,20-22] have demonstrated improvements in pain and outcome scores following surgical intervention, irrespective of the status of rotator cuff healing. The outcome measures that require measurement of strength or active shoulder motion (Constant[23] and University of California, Los Angeles [UCLA][24] scoring systems) demonstrated improvement with tendon healing, whereas those that evaluate subjective patient outcomes failed to show a difference between patients with healed tendons and those with discontinuity of the rotator cuff tendon at the final imaging follow-up evaluation[8-10,19,22,25-41] (Table II). Improvements in strength and shoulder motion were also noted in the majority of studies (Table III), indicating that there is likely an improvement in these components but that patient-perceived function is not significantly affected by the status of tendon healing.

Surgical Factors

Repair Technique: Open Versus Arthroscopic

Surgeons debate the benefits of both open and arthroscopic techniques, citing factors such as pain, postoperative outcomes, the speed and ease of the procedure, and postoperative complications. However, the purpose of this review is to specifically evaluate the healing rates between these techniques. Using an open technique, Harryman et al. demonstrated by ultrasound that 80% of the tendons were intact postoperatively when only the supraspinatus was involved, but that more than half of the tendons were not healed when the tear extended into the infraspinatus or with subscapularis involvement[10]. In a study comparing open and arthroscopic repairs, there was no difference in Constant score, range of motion, or healing in a comparison of arthroscopic repair and the mini-open technique[35]. Using the classification system proposed by Post et al.[42], in which small tears were defined as <1 cm, medium tears as 1 to 3 cm, large tears as >3 to 5 cm, and massive tears as >5 cm, Bishop et al.[43] demonstrated that the open technique was superior in large and massive tears (62% and 40%, respectively, were intact) compared with an arthroscopic technique, in which only 24% of repairs were intact in large tears and 12% in massive tears ($p = 0.04$). Systematic reviews of open and arthroscopic techniques found no difference between these techniques[44,45].

Repair Technique: Single Row or Double Row?

Another controversial topic in rotator cuff repair is the use of single or double-row techniques. The theoretical benefit of double-row techniques allows for increased compression of the tendon against the rotator cuff footprint compared with the improved speed and reduced cost of single-row fixation. Nho et al. were unable to demonstrate that the single or double-row technique could predict healing[46]. In a study of large and massive rotator cuff tears, Mihata et al. noted discontinuity of the rotator cuff tendon in 11% of single-row repairs, 26% of double-row repairs, and only 5% when a compression double-row technique was used[37]. DeHaan et al.[47], in a systematic review of Level-I and II studies, noted a 43.1% failure rate in single-row repair compared with 27.2% for double-row repair, which may represent clinically relevant improvement; however, this did not reach significance.

Repair Technique: Tying Knots Medially or All Knotless Repairs?

A recent systematic review by Mall et al.[4] evaluated the stiffness, hysteresis, gap formation, and ultimate load to failure of

TABLE II Rotator Cuff Healing and Outcomes ➤

			Pain *(mean score)*		Mean Outcome Score 1		
Study	No. of Shoulders	Imaging*	Intact	Defect†	Type‡	Intact	Defect†
Anderson et al.[28] (2006)	52	US			L'Insalata	92	94
Boileau et al.[27] (2005)	65	CTA and MRI			Constant	86	79**
Castagna et al.[26] (2008)	29	US			Constant	73	55**
Charousset et al.[29] (2008)	114	CTA			Constant	83	74**
Charousset et al.[9] (2010)	81	CTA			Constant	82	72
Cho and Rhee[8] (2009)	169	MRI	1.5	1.6			
Cole et al.[30] (2007)	49	MRI	1.4	1.5			
DeFranco et al.[31] (2007)	30	US			Penn	96	83**
Flurin et al.[32] (2007)	576	CTA and MRI			Constant	84	78
Frank et al.[41] (2008)	25	MRI			Constant	90	88
Harryman et al.[10]†† (1991)	105	US			Patient satisfaction	98	86
Huijsmans et al.[33] (2007)	210	US			Constant	81	76**
Lafosse et al.[34] (2007)	105	CTA and MRI	13.3	11.2**	Constant	81	76
Liem et al.[35] (2007)	53	MRI			Constant	86	79
McCarron et al.[19] (2013)	13	MRI			Penn	93‡‡	80‡‡
Mellado et al.[36]§§ (2005)	28	MRI			Constant		
Mihata et al.[37] (2011)	195	MRI			JOA	98	86**
Nho et al.[38] (2009)	93	US					
Oh et al.[39] (2010)	177	CTA	2	1	Constant	69	70
Papadopoulos et al.[25] (2011)	27	US			Constant	85	76
Voigt et al.[40] (2010)	45	MRI	15‡‡	16‡‡	Constant	93‡‡	94‡‡
Yoo et al.[22] (2009)	22	MRI	1.2	1.3	Constant	82	82

*US = ultrasound, CTA = computed tomography arthrography, and MRI = magnetic resonance imaging. †Defect refers to rotator cuff defects at the time of follow-up imaging. ‡JOA = Japanese Orthopaedic Association. §SST = Simple Shoulder Test, and ASES = American Shoulder and Elbow Surgeons. #UCLA = University of California, Los Angeles. **Significant difference. ††In the study by Harryman et al., no pain score was given; however, thirty-seven of forty intact shoulders and twenty-six of thirty-seven shoulders with a defect were painless. With regard to functional outcome, the patients had an improved ability to comb hair, overhead activities, pull, perineal care, lift, dress, carry 10 to 15 lb (4.5 to 6.8 kg), eat with a utensil, and perform usual work with intact repair. ‡‡Value may be inexact as it was taken from graph, without a published exact value. §§In the study by Mellado et al., coronal defect size negatively correlated with Constant score.

suture-bridge techniques in which knots were tied at the medial row compared with those that used knotless repairs. They found greater hysteresis, less gap formation, and higher ultimate load in the medially knotted groups. However, this systematic review was based on biomechanical studies only, and there are no clinical data supporting this advantage with regard to rotator cuff healing. Furthermore, this is complicated by the fact that the threshold of fixation strength needed for early motion and rotator cuff healing is unknown.

Suture Anchors

Suture anchors vary considerably by brand, material, anchor design, size, loaded suture material, loaded suture numbers, as well as the applicability of placement location and repair configuration. With regard to anchor design, a biomechanical study testing multiple anchor types by Barber et al.[48] found that mean cancellous loads to failure for rotator cuff anchors ranged from 262.7 to 611.7 N in a variety of anchor types. To our knowledge, no current study has addressed the healing rates related to the anchor material, which includes the options of metal-titanium, multiple biocomposite materials, polyetheretherketone (PEEK), and more recently, all-suture anchors[6]. Several studies have described specific complications related to metal[49] and to bioabsorbable[50] and biocomposite anchors[51].

Preparation of the Greater Tuberosity

Preparation of the greater tuberosity is considered a standard procedure to maximize tendon-to-bone healing. However, there is concern that, in osteoporotic bone, this may compromise anchor fixation. St. Pierre et al. found no significant difference in tendon healing between a cancellous trough or cortical bone in a goat model[52]. Snyder and Burns described a "crimson duvet" technique in which microfracture of the tuberosity is performed to create a bed of blood and healing factors on which the rotator cuff will lie[53]. A similar technique demonstrated trends, but no significant differences, in rotator

TABLE II (*continued*)

Mean Outcome Score 2			Mean Outcome Score 3		
Type§	Intact	Defect†	Type#	Intact	Defect†
SST	11	8**			
ASES	92	91	UCLA	33	32
ASES	92	97			
Function					
ASES	98	77**	UCLA	35	27**
ASES	94	88			
ASES	86	92			
			UCLA	32	29
ASES	87	86			

cuff healing (66% healed) compared with standard tuberosity preparation (53% healed)[54]. Multivariate analysis of the outcome of rotator cuff healing demonstrated only tear location and size (tears in the supraspinatus only; $p = 0.04$) and fatty infiltration (grade 0 to 2) assessed on MRI ($p = 0.007$) to be independent predictors of rotator cuff healing[54].

Acromioplasty

Full-thickness rotator cuff tears have been associated with the presence of an acromial spur[55]; however, the spur itself is unlikely to be the cause of the rotator cuff pathology, and the need for an acromioplasty at the time of rotator cuff repair is unclear. In a systematic review and meta-analysis of acromioplasty with rotator cuff repair, no difference was noted in the number of repeat surgical procedures between patients with and without acromioplasty performed at the time of the rotator cuff repair[56]. A prospective, randomized, comparative Level-II study published after the submission of the aforementioned systematic review demonstrated no difference in rotator cuff healing ($p = 0.48$) between patients undergoing acromioplasty and those with rotator cuff repair alone[57].

Structural Augmentation

Recent advances have focused on structural augmentation of the rotator cuff tendon, as the tendon is a common point of failure in biomechanical studies[7]. While a variety of materials have been described for this use[58], augmentation is primarily used in the setting of large tears with insufficient coverage of the humeral head. In routine repairs, a recent biomechanical analysis by van der Meijden et al.[59] found that augmentation with a collagen patch did not influence biomechanical properties of a repair compared with double-row repair without augmentation or an intact tendon. Conversely, a biomechanical study of human dermal matrix grafts (GRAFTJACKET; Wright Medical Technology, Arlington, Tennessee) found that augmentation of single-row repair with this material had greater maximum load to failure than single-row repair without augmentation (mean, 560.2 N versus 345.7 N)[60]. At a minimum of one year of follow-up, Bond et al. found that thirteen of sixteen massive, irreparable tears had GRAFTJACKET grafts that incorporated to the rotator cuff tendon and remained attached to the greater tuberosity[61]. A recent prospective, randomized study demonstrated a significantly greater number of intact repairs (85% versus 40%; $p < 0.01$) for two tendon tears; however, as with most studies examining the use of augmentation patches, this was a relatively small study with only twenty patients in each group[62]. Several other clinical studies have demonstrated poor results or no benefit with the use of these augments and have recommended against their use[63-65].

TABLE III Rotator Cuff Healing and Function

Study	No. of Shoulders	Advanced Imaging Technique*	Mean Strength			Mean Active Forward Elevation (deg)	
			Measurement System†	Intact	Defect	Intact	Defect
Anderson et al.[28]‡ (2006)	52	US	MSTR	1.05	0.62§	175	175
Charousset et al.[9] (2010)	81	CTA		9.5	4.7§		
Cho and Rhee[8] (2009)	169	MRI		7.9	5.3§	165	163
Cole et al.[30] (2007)	49	MRI	Dynamometer *(kg)*	5.8	3.9	174	164§
Flurin et al.[32] (2007)	576	CTA and MRI		14.5	10.7§		
Harryman et al.[10] (1991)	105	US		13	SD#	132**	SD#
Huijsmans et al.[33] (2007)	210	US	Constant score with Isobex	4.2	2.4§	170	160§
Lafosse et al.[34] (2007)	105	CTA and MRI	Dynamometer *(kg)*	12.9	11.4	151	142
Liem et al.[35] (2007)	53	MRI		13.9	8.4§		
McCarron et al.[19]†† (2013)	13	MRI					
Mihata et al.[37] (2011)	195	MRI				171	145
Nho et al.[38] (2009)	93	US	Dynamometer (FE; ER)	4.9; 4.9	4.3; 4.2§	173	171
Voigt et al.[40] (2010)	45	MRI		10**	10**	160**	160**

*US = ultrasound, CTA = computed tomography arthrography, and MRI = magnetic resonance imaging. †If not indicated, units were given as part of the Constant scale or the measurement system was not specified. MSTR = mean strength ratio, FE = forward elevation, and ER = external rotation. ‡In the study by Anderson et al., shoulders had improved strength in forward elevation and external rotation, but not internal rotation. §Significant difference. #SD = significantly different but value was not reported. **Value may be inexact as it was taken from a graph without a published exact value. ††No difference between groups was found with respect to strength, but the values were not reported.

Platelet-Rich Plasma (PRP)

With the recent increase in basic-science research related to PRP and its potential clinical benefits, its use in enhancing rotator cuff healing has been studied by several authors[66-69]. Results of current studies have not shown evidence of improved or accelerated functional outcomes or structural healing with the use of PRP augmentation in rotator cuff repairs. A recent systematic review and meta-analysis of five studies with Level-I, II, or III evidence found no difference in rotator cuff healing when PRP was used during repair[70]. However, when the data were broken down by tear size, the results favored the use of PRP in small and medium tears, defined as tears of <3 cm, to improve healing. Since submission of that review, another study, by Rodeo et al.[71], found no difference in the number of healed tendons on ultrasound at twelve months in patients with and without augmentation with platelet-rich fibrin matrix; however, linear regression analysis found that the use of the platelet-rich matrix was a significant predictor of a persistent defect at twelve weeks and may actually lead to an increased complication rate with a higher infection rate. Another randomized controlled trial demonstrated no improvement in structural integrity with the use of platelet-rich fibrin matrix at one year after surgery[72].

Postoperative Rehabilitation

Rehabilitation protocols vary widely by surgeon preference and can be modified on the basis of the tear size, location, and quality of the repair. While protecting the repair is thought to be important, Galatz et al.[1] noted that complete removal of load was detrimental to rotator cuff healing. Similarly, Hettrich et al.[73] found that, at eight weeks following rotator cuff repair, rats treated with BOTOX (botulinum toxin A) had significantly lower load to failure and less bone volume, total mineral content, and total mineral density. Voigt et al.[40] demonstrated that patients with fewer therapy visits after rotator cuff surgery had improved shoulder function compared with those who had more, but they did not analyze rotator cuff healing as part of the study. Two studies[74,75] that examined healing using early motion compared with delayed motion after rotator cuff repair found no difference in healing between the groups, but the studies were limited by size, with a total of only eighteen rotator cuff defects in 132 patients combined. Lee et al.[74] found more failures among patients in an aggressive early passive motion group (23%) compared with a limited early motion group (8.8%), but this difference did not reach significance. In a prospective randomized study of early or delayed motion after transosseous equivalent rotator cuff repairs, Cuff and Pupello found no difference ($p = 0.47$) in healing between early motion (85% healed) and delayed motion (91%) using ultrasound evaluation at one year[75].

Patient-Specific Factors

Despite the advances in surgical techniques to optimize the strength of the repair and compression of the tendon to the tuberosity, some rotator cuff repairs fail to heal. Recent studies have focused on the biologic and patient-specific factors that may contribute to the healing environment.

TABLE III (*continued*)

Mean Active Abduction (*deg*)		Mean Active External Rotation (*deg*)		Mean Active Internal Rotation (*deg*)	
Intact	Defect	Intact	Defect	Intact	Defect
		85	78	56	66
		53	52		
168	153§	79	66§		
		41	SD#	T7	SD§#
		63	52§	T11	L1
		76	68		
165**	170**	65**	65**	90**	90**

Age

Numerous studies[8,9,27,40,43,76,77] have demonstrated an age difference in healing rates after rotator cuff repair (Table IV). In a large observational study examining the natural history of rotator cuff disease, patients without rotator cuff tears were an average of forty-nine years old; those with unilateral tears, an average of fifty-nine years old; and those with bilateral tears, an average of sixty-eight years old[78]. However, increasing age may simply represent a poor healing environment with reduced biomechanical properties of the tendon. A study of 272 patients evaluated with postoperative CT arthrography or ultrasound found that those with rotator cuff healing were significantly younger than those without; yet after multivariate analysis, the only independent predictors of healing were bone mineral density, fatty infiltration of the infraspinatus, and the amount of retraction of the tear at the time of surgery[79]. A similar study also found that, while age was a significant factor in rotator cuff healing when univariate analysis was used, multivariate regression analysis showed that the independent predictors were tear retraction and fatty degeneration only[39]. While increasing age may represent a diminished healing environment, many studies have demonstrated excellent outcomes in older patients[80-82]. Worland et al.[82], using magnetic resonance arthrography, found that 80% of patients over the age of seventy years had a healed rotator cuff after repair.

Healing Environment

Several studies have noted differences in the biologic surroundings of tendons that heal and those that have persistent defects. The molecules matrix metalloproteinase (MMP)-1[83], MMP-9[83], and tumor necrosis factor (TNF)-alpha[84] have each been shown to negatively affect the rotator cuff repair tissue in animal studies, and thus inhibitors may improve rotator cuff healing[85]. Transforming growth factor (TGF)-beta 3[86,87] and recombinant human parathyroid hormone (rhPTH)[2] when delivered in appropriate amounts can improve material properties of the rotator cuff repair tissue in a rat model. Human studies are ongoing to address the clinical applicability of these biologic factors in improving rotator cuff healing rates.

Tear Characteristics

Tear size influences rotator cuff healing, with larger tears having a lower rate of healing. Using the classification system proposed by Post et al.[42], Mihata et al.[37] found that at a minimum two-year follow-up with MRI, five (4%) of 135 small or medium tears were not healed compared with thirteen (22%) of sixty large or massive tears ($p < 0.001$). Another study[8] showed 97% healing in small tears, 87% in medium tears, and 59% in large and massive tears. Charousset et al.[9] reported that 29% of thirty-nine small or medium tears were not healed compared with 100% (six of six) in the massive tear group ($p < 0.01$).

Other studies have categorized outcomes on the basis of the number of tendons involved. Nho et al. demonstrated healing in 90% of single tendon tears and in only 49% of multitendon tears[76]. That study also found that the average size of the preoperative defect in the healed group was 2.8 cm compared with 4.4 cm in those that did not heal. Similar results were found by Tashjian et al.[88], with healing in 67% of single tendon tears and in only 36% of multitendon tears. Millar et al.[89] demonstrated a correlation between recurrent defect size and the preoperative tear size. Preoperative tear size was significantly less in the group with intact rotator cuff repairs at the time of final follow-up compared with the group without healed tendons[43]. The rotator cuff repair failure rate in a study looking at large or massive tears was 46%; however, the defects were smaller and, following repair, the outcomes were improved and there was no progression of fatty atrophy[22].

TABLE IV Rotator Cuff Healing by Patient Age

Study	No. of Shoulders	No. of Shoulders with Healed Rotator Cuff	Average Age of Patients with Healed Rotator Cuff (*yr*)	Average Age of Patients with Rotator Cuff Defect (*yr*)
Anderson et al.[28] (2006)	52	43 (83%)	57	61
Bishop et al.[43] (2006)	72	43 (60%)	61	67*
Boileau et al.[27] (2005)	65	46 (71%)	58	68*
Castagna et al.[26] (2008)	29	18 (62%)	50	68*
Charousset et al.[9] (2010)	81	47 (58%)		
Cho and Rhee[8] (2009)	169			
<50 yr	49	43 (88%)		
51-60 yr	68	54 (79%)		
≥61 yr	52	34 (65%)		
Cole et al.[30] (2007)	49	38 (78%)	55	64*
DeFranco et al.[31] (2007)	30	18 (60%)	51	64*
Flurin et al.[32] (2007)	576			
<50 yr	104	91 (87%)		
50-59 yr	249	199 (80%)		
60-69 yr	153	104 (68%)		
≥70 yr	70	39 (56%)		
Frank et al.[41] (2008)	25	22 (88%)	57	61
Harryman et al.[10] (1991)	105	68 (65%)	64	68
Huijsmans et al.[33] (2007)	210	174 (85%)	57	64
Liem et al.[35] (2007)	53	40 (76%)	60	65*
McCarron et al.[19] (2013)	13	9 (69%)	60	55
Nho et al.[38] (2009)	93	63 (68%)	57	63*
Oh et al.[21] (2011)	53	31 (59%)	59	63*
Oh et al.[39] (2010)	177	122 (69%)	58	64*
Papadopoulous et al.[25] (2011)	27	13 (48%)	54	64*
Voigt et al.[40] (2010)	45	32 (71%)	60	67*
Total	1924	1391 (72%)	58	65

*Significant difference.

Tissue quality can also play a role in determining the likelihood of rotator cuff healing. Nho et al.[76] showed that 84% of patients with normal quality tissue healed after rotator cuff surgery compared with 55% of patients who had degenerative tissue (p = 0.002). Another study showed fewer failures with normal tissue (19%) compared with those with degenerative or delaminated tissue (48%)[11]. Fatty infiltration and atrophy of the rotator cuff tendon can be evaluated using all advanced imaging modalities[90] and can provide information about the quality of the tendon. Fatty infiltration correlates with healing rates[79]. Rotator cuff repairs with a fatty infiltration index of <1 were reported to have a lower rate of failures (19%) than those with an index of >1 (67%); the difference was significant (p < 0.001)[9]. Cho and Rhee[8] found a 100% failure rate in repairs with a global fatty degeneration index of >2. Using the Goutallier classification system, Voigt et al.[40] found that 85% of unhealed tendons had fatty infiltration that was Goutallier grade 2 or higher, whereas only 41% of intact tendons had Goutallier grade 2 or more; however, with the number of patients, the difference was not significant (p = 0.56).

Duration of Symptoms

The duration of symptoms has been associated with the chronicity of the tear, which may influence both the quality of the tissue and affect the quality of the repair. Cho and Rhee[8] demonstrated a healing rate of 83% in patients who had surgery within one year after the onset of symptoms and a healing rate of 71% in those treated surgically after twelve months; however, the difference was not significant. Another study described a significantly greater rate of persistent defects in patients with symptoms for more than twelve months than in those with symptoms for less than twelve months (60% and 26%, respectively; $p < 0.05$)[9]. However, Voigt et al.[40] did not find that the duration of symptoms was a factor in the prevalence of rotator cuff repair failure in their study of supraspinatus repair using the suture-bridge technique. Traumatic tears have been assumed to require relatively urgent repair to improve the ability to mobilize the tendon and achieve an anatomic reduction, as well as to reduce the risk of chronic muscle and tendon changes that may influence healing. In a systematic review of traumatic rotator cuff tears[91], small tears and a younger patient age were factors that improved rotator cuff healing, but the effect of time to rotator cuff repair in relation to rotator cuff healing was assessed in only one study[92], with no differences found between tears repaired early and those repaired in a delayed fashion. While several studies have demonstrated improvements in outcomes scores with more urgent repair[93-96], the present study specifically evaluates the data related to rotator cuff healing.

Osteoporosis

Poor bone quality may affect fixation strength in rotator cuff repairs and can also be an indicator of poor tissue quality in an elderly patient. Charousset et al.[9] found that healing was less likely in patients with poor bone quality (67% had defects) compared with those with normal bone quality (36% had defects) ($p < 0.05$). In a multivariate analysis of rotator cuff healing, Chung et al.[79] found that bone mineral density was one of the independent factors predicting rotator cuff healing along with fatty infiltration of the infraspinatus and the amount of retraction. The association of osteoporosis with age has been well-described. A study of the bone mineral density of the greater and lesser tuberosities of osteoporotic humeral heads found that the posteromedial portion of the greater tuberosity had the highest density, and there was a significant inverse correlation of bone quality and age[97].

Diabetes

Diabetes may impact healing because of an impeded vascular response or poorer nutrition profiles. Bedi et al.[98] demonstrated less fibrocartilage and organized collagen in diabetic rats, which translated into a significantly reduced load to failure and stiffness. Abate et al.[99] demonstrated a higher incidence of full-thickness rotator cuff tears in their diabetic patients. After repair, Clement et al.[100] found inferior outcome measures and more rotator cuff defects in diabetic patients. Chen et al.[101] also found slightly higher numbers of failures in diabetic patients, although the sample size was too small for this to reach significance.

Smoking

Basic-science studies have demonstrated that nicotine causes a delay in tendon-bone healing with poor type-I collagen expression and inferior biomechanical properties in a rat model[3]. Baumgarten et al.[102] noted a dose and time-dependent relationship between smoking and the presence of rotator cuff tears. A study evaluating factors associated with rotator cuff healing noted that healing occurred in 84% of nonsmokers and only 68% of smokers; however, the difference was not significant, likely because of the lack of power to show a true difference[76].

Nonsteroidal Anti-Inflammatory Drug (NSAID) Use

While NSAIDs benefit pain control and reduce the amount and duration of narcotic usage after surgery, there is concern that use of these medications may impede tendon-to-bone healing. Several studies using a rat model have demonstrated impaired tendon quality (poor collagen organization and reduced size) and a reduction in biomechanical properties, including stiffness, energy absorption, and pullout strength[103-105]. Clinical studies have noted reduced bone healing or spinal fusions when NSAIDs have been used[106]. However, clinical studies evaluating rotator cuff healing and NSAID usage are thus far inadequate.

Overview

Rotator cuff healing is influenced by a combination of mechanical and biologic factors. Healing requires biomechanical fixation utilizing repair techniques that provide adequate strength, stability, and compression against the rotator cuff footprint, while maximizing the biologic factors that allow ultimate tendon-to-bone healing. Further studies are needed to elucidate the optimal combination of factors to maximize rotator cuff healing. ■

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