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Partial Thickness Rotator Cuff Tears

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Partial-thickness rotator cuff tear (PTRCT) is not single disease entity but one phase of disease spectrum. Symptoms of PTRCT vary from being asymptomatic to severe pain leading to deterioration in quality of life. Pathogenesis of degenerative PTRCT is multifactorial. Whereas articular sided PTRCT is usually caused by internal causes, both internal and external causes have important role in bursal sided PTRCT. A detailed history, clinical examination and magnetic resonance angiography are used in the diagnosis of PTRCT. Treatment of PTRCT is chosen based on age, demands of patients, causes and depth of tear. In most patients, non-operative treatment should be initiated. Whereas debridement can be done for less than 6 mm of articular sided PTRCT and in less than 3 mm of bursal sided PTRCT, repair techniques should be considered for higher grade PTRCT than that. Although the effect of acromioplasty is not clear, acromioplasty may be performed when the extrinsic causes appear to be the cause of tear. Either transtendon repair technique or repair after tear completion provided satisfactory clinical outcomes in treatment of articular sided PTRCT.
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Key Words: Rotator cuff; Partial thickness tear; Articular side; Bursal side

Introduction

Partial-thickness rotator cuff tear (PTRCT) have been recognized as an asymptomatic consequence of the ageing process.[1,2] However, after recent advances in basic science, imaging modalities and treatment techniques, PTRCT is now recognized as a part of disease spectrum and not as a single entity. This spectrum of rotator cuff disease ranges from rotator cuff edema, inflammatory tendinitis and rotator cuff fibrosis progressing to partial or full-thickness tears. PTRCT is not rare and its prevalence is even expected to increase with a rise in geriatric population.[1,3] In this review the diagnosis, classification, treatment options, surgical indications, surgical techniques and its outcomes with regard to PTRCT will be discussed.

Incidence

The reported incidence of PTRCT is 13−32% in cadaveric studies.[4,5] An in vivo study using magnetic resonance imaging (MRI) in asymptomatic population reported the overall prevalence of PTRCT as 20% and that of PTRCT in the patients aged older than 60 years as 26%.[3] Ultrasonography studies demonstrated that the prevalence of PTRCT was 17% in the asymptomatic volunteers, and 7% in the symptomatic patients.[6] The prevalence of articular sided tears is 2−3 times more than that of bursal side.[4] Although the incidence of PTRCT increases with age,[7] it may not be necessarily associated with symptoms.

Natural History

The natural history of PRTCT has not been clearly identified; several studies have reported tear progression with time and age.[8,9] In a study on progression of tears on arthroscopic examination in 40 patients, the tear size increased in 4 (10%) patients, progressed to the full-thickness tear in 11 (28%) patients, reduced in 4 (10%) patients and the tear healed in 4 (10%) patients.[9] Even though a few studies have reported the potential for spontaneous healing of torn cuff tendons, most studies have shown that the torn tendon is less likely to heal spontaneously.[10-13] In histologic studies no evidence of active healing of torn

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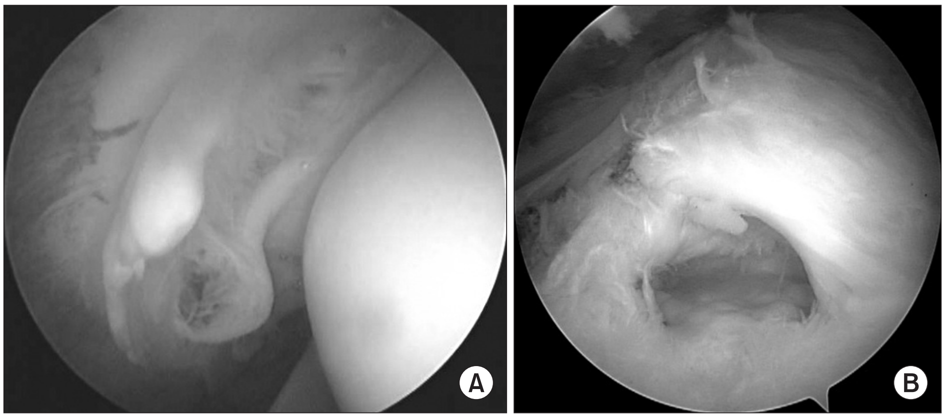

Fig. 1. (A) Arthroscopic view of articular sided partial-thickness rotator cuff tear. (B) Arthroscopic view of bursal sided partial-thickness rotator cuff tear.

end of the tendon and a rounded proximal stump, retracted and avascular appearance of cuff stump was reported.[14] All these findings supported limited potential for spontaneous healing of PTRCT. In an immunohistochemical study, some chemical mediators such as interleukin-1β, cathepsin D, and matrix metalloprotease-1 were found to be increased with the macrophages and multinucleated giant cells present in the injured supraspinatus tendon and reparatory granulation tissue.[12] They may contribute to the rotator cuff injury by weakening the insertion site.

Classification

PTRCT can be classified into articular sided tear (Fig. 1A), bursal sided tear (Fig. 1B), intratendinous tear and combined type tear. Ellman[15] further classified PTRCT based on the location of tear (A: articular, B: bursal, C: intratendinous) and on the depth of tear (grade 1: <3 mm, grade 2: 3−6 mm, grade 3: >6 mm) (Table 1). Synder et al[16] coined the term "partial articular sided tendon avulsion" for PTRCT on the articular sided. He also described a classification of partial tears based on the location of the tear (articular, bursal, total) and severity of the tear (grade 1−4). Conway[17] described articular sided partial tear accompanying intratendinous tear as partial articular tears with intratendinous extension. Recently, Habermeyer et al.[18] pointed out the limitation of the classification of Snyder et al.[16] and Ellman[15] and proposed a new classification based on 2-dimensional sagittal and longitudinal extension of the tear.

Pathogenesis

The injury mechanisms of articular sided and bursal sided PTRCT are different because of the difference in vascularity, biomechanical and histological characteristics. A critical zone of avascularity close to the insertion of the supraspinatus tendon into the humeral head[19] and its histological correlation with the site of rotator cuff degeneration has been described.[20] This sparse vascular distribution was found mainly on the articular sided which was a significant factor in the pathogenesis of degenerative rotator cuff tears. A cadaveric study showed the histological and biomechanical differences between bursal sided and articular sided tendon layer.[21] This difference could make articular sided tendon layer more vulnerable to tear than bursal sided tendon layer.

Table 1. Ellman's Classification of Partial-thickness Rotator Cuff Tear

Location	Grade
A: Articular surface	1: <3 mm deep
B: Bursal surface	2: 3–6 mm deep
C: Interstitial	3: >6 mm deep

Etiology of PTRCT can be classified into intrinsic, extrinsic and traumatic causes. Intrinsic causes include age related metabolic and vascular changes which can lead to degenerative tear, and differential shear stress which leads to intratendinous tears especially in the throwing arthlete.[22,23] Extrinsic causes include subacromial impingement, inflammatory bursitis and internal impingement. A spur of undersurface of acromion was always associated with a rotator cuff tear; however, the converse was not always true.[22] In an animal model, the undersurface of the acromion of test group of rats was thickened with plate like bony transplants to cause impingement. As compared to control group which did not have any rotator cuff tears, the test group demonstrated bursal sided tears. This demonstrates the role of external source of impingement as a cause of bursal sided tears.[24] Although the pathogenesis of rotator cuff tear is controversial, it is likely that both intrinsic and extrinsic causes are associated with the pathogenesis of PTRCT.

Diagnosis

Clinical Presentation

The symptoms of PTRCT are variable depending on concomitant disease. The most common symptoms are pain and stiffness of the shoulder joint. Pain is usually severe at night and aggravated by overhead elevation of the arm. Patients may complain of weakness of the upper arm. In a previous study, 74% of the patients with PTRCT felt more than moderate pain, whereas only 50% of those with the full thickness rotator cuff tear (FTRCT) did.[4] The level of substance P which is a pain mediator in the subacromial bursa was higher in PTRCT patients than in the FTRCT patients.[25] Bursal sided PTRCT are more painful than articular sided partial tears due to more inflammatory mediator like interleukin-1β, interleukin-1 receptor agonists in subacromial space than that in the intra articular space.

PTRCT is more likely to lead to stiffness of affected shoulder than FTRCT. The tear of 1/3 or 2/3 of the thickness of supraspinatus tendon had little effect on force transmission and hence usually does not present with weakness in abduction.[26] A partial tear of rotator cuff tendon can lead to localized strain concentration in the adjacent area of tendon.[27] This strain concentration may be cause of the more severe pain in PTRCT. In PTRCT, although, mechanical force transmission may be preserved, tension concentration on the normal fiber during abduction may contribute to shoulder pain and stiffens.[28]

Physical Examination

The clinical diagnosis of PTRCT is based on an integrated assessment based on detailed history taking, physical examination and the radiologic results. Visual inspection of muscles around shoulder joint is performed to detect muscle atrophy or asymmetry as compared to unaffected side. Range of shoulder motion including active and passive motion, and muscle power during forward flexion, abduction, adduction, external rotation and internal rotation should be examined. Tests like sulcus sign, apprehension test and relocation test are useful for evaluation of accompanying shoulder instability. Biceps tendon lesions which can be associated with rotator cuff lesion should be examined with tests for biceps lesion like O'Brien test. Cervical spondylosis is an important differential diagnosis and the tenderness, range of motion of cervical spine should be examined. Provocative tests such as Spurling maneuver are very useful for discrimination. After ruling out other differential diagnoses, the symptoms which arise from FTRCT are evaluated. The symptoms of rotator cuff tear can be divided into the inflammatory symptoms and the mechanical symptoms. Inflammatory symptoms include pain, painful arc and impingement sign. Mechanical symptoms and signs include muscle power weakness, muscle atrophy, crepitus and drop arm sign. The final differential diagnosis of PTRCT based on the physical examination is difficult, because the symptoms of the PTRCT are atypical and similar to those of impingement syndrome without rotator cuff tear and small FTRCT. For reasons mentioned above, PTRCT was identified by chance when arthroscopic surgery was performed in patients with impingement syndrome.

Radiologic Evaluation

A variety of radiologic modalities are used to diagnose PTRCT currently. In the past, arthrography and bursography have been used as the primary imaging modalities for rotator cuff tear. Due to their low sensitivity (15−83%) and specificity (25−67%) and availability of better methods these modalities are rarely used now.[29-31]

Ultrasonography and MRI have become the gold standard for diagnosis of rotator cuff tear. A mixed hyperechoic/hypoechoic focus in the supraspinatus tendon has a sensitivity of 93%, specificity of 94%, positive predictive value of 82%, and negative predictive value of 98% of diagnosing a PTRCT.[32] A 'focal heterogeneous hypoechogenicity' has a sensitivity of 95%, specificity of 90%, positive predictive value of 97%, negative predictive value of 94%, and accuracy of 94% of detecting a PTRCT.[33] The limitation of ultrasonography is the accuracy rate depends on the experience and the skill of the examiner in spite of its relatively low cost, good patient tolerance and reported high accuracy rate.

PTRCT on the MRI has increased signal intensity and ab-

Fig. 2. (A) Articular sided partial-thickness rotator cuff tear on magnetic resonance imaging (MRI) scan. (B) Interstitial partial-thickness rotator cuff tear on MRI scan. (C) Bursal sided partial-thickness rotator cuff tear on MRI scan.

normal morphology without discontinuity on T1 images and increased signal intensity with focal defect on T2 images (Fig. 2).[7] PTRCT can be differentiated from tendinosis based on MRI image because tendinosis showed high signal intensity on T1 and Proton images but low signal intensity on T2 image. Ultrasonography and MRI have been shown to have comparable accuracy for identifying and measuring the size of PTRCT and FTRCT.[34] MRI and ultrasonography have been reported to be less useful for PTRCT than for FTRCT.[35] The accuracy of MRI and ultrasonography for PTRCT is 73% and 70% respectively, whereas that for FTRCT it was 95% and 88% respectively. The authors emphasized that in the hands of well trained and experienced orthopedic surgeon utility of ultrasonography is comparable to MRI. MRI helps to evaluate the remainder of the shoulder anatomy however is relatively costly. With the introduction of the magnetic resonance angiography (MRA), a recent study reported sensitivity of 84%, specificity of 96%, positive predictive value of 93%, and overall accuracy of 91% for diagnosis of PTRCT.[36] MRA is the most sensitive and specific technique for diagnosing PTRCT. Ultrasonography and MRI are comparable in both sensitivity and specificity.[37]

Treatment

Non-operative Treatment

The treatment options depend on the causes of tear, the location of tear and the symptoms and activities of patients. Management is initiated with rest, activity modification and non-steroidal ant-inflammatory drugs. Pain relief due to reduction in inflammation is expected with this treatment. For patient with stiff shoulder, after pain relief, physical therapy and exercises to recover the range of motion should be initiated. Subacromial or intra-articular corticosteroid injections have certain benefits for pain relief. As patients recover range of motion, strengthening exercises for periscapular muscles should be initiated. There are no standardized, long-term follow up studies evaluating the clinical outcomes of patients with PTRCT treated non-operatively. Although available studies indicate that PTRCT progress with time, it is possible for patients to improve symptomatically with non-operative treatment. Non-operative treatment can usually be continued for more than 6 months with satisfactory clinical outcomes. However, non-operative treatment is less effective in treatment of bursal sided PTRCT.[29,38]

Operative Treatment

With symptom aggravation or failure of conservative treatment for a reasonable period of time, operative treatment can be considered. Although the timing of operation is variable it is usually after trial of non-operative treatment for 3−6 months and no more than 1 year. Operative treatment depends on the severity of symptoms, degree of improvement with non-operative treatment and the demands of patients. Various options include debridement, acromioplasty, repair and combination of these techniques using arthroscope or mini incision. Choice of treatment is determined based on the location and the depth of tear (Fig. 3). However, there are times when visual inspection of the field does not reveal the exact site of PTRCT. Fukuda color test can be used during mini open approach.[39] It is done

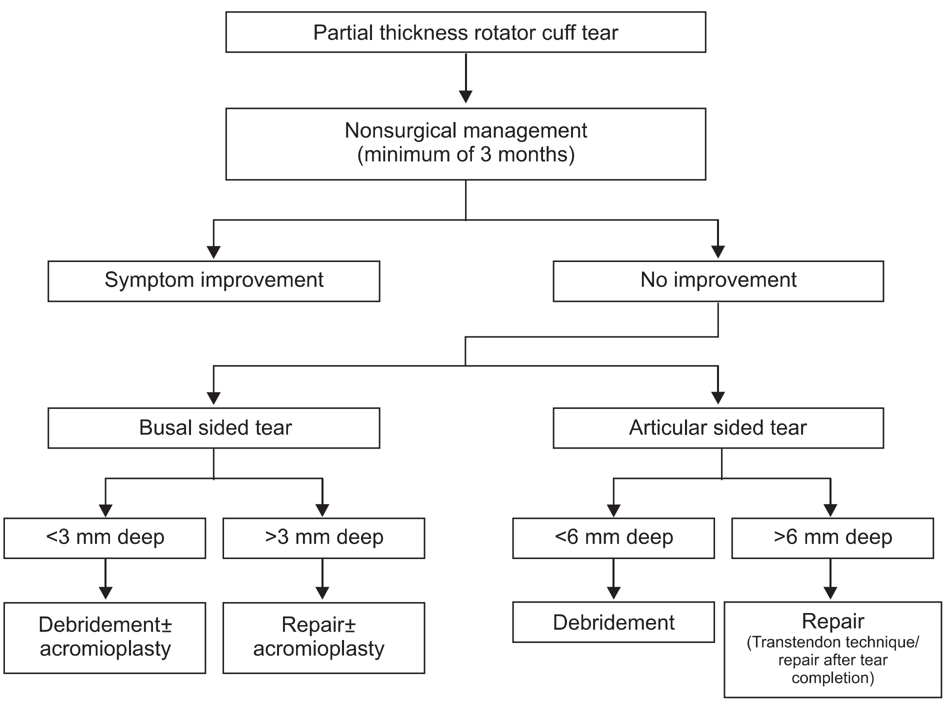

Fig. 3. Treatment algorithm for partial-thickness rotator cuff tear.

by checking for dyed cuff tendon region after injecting indigo carmine or the methylene blue into the glenohumeral joint and taking the shoulder through its range of movement. When using arthroscopic approach, suture marking technique and bubble sign are used. The bubble sign is demonstrated by directing normal saline into the suspicious lesion. In the operative field, the tear size can be measured using a variety of tools like the probe, tip of shaver and special ruler for arthroscopic approach. The tear should be debrided first with a shaver to define the extent of the tear. For bursal sided tear, the extent is determined from the edge of intact margins in the anteroposterior plane and from the footprint to the torn edge in the coronal plane. For the articular sided tear, the extent is measured from lateral margin of the articular surface to the torn edge of the tendon and the distance between the torn tendon edges in the anteroposterior plane.

Debridement

Bursal or articular sided PTRCT of grade 1 and articular sided PTRCT of grade 2 can be treated by debridement with or without acromioplasty. Debridement stimulates healing as it not only removes inflammatory cells and mediators, but also decreases the mechanical irritation in the subacromial space and glenohumeral joint. In addition, it helps to evaluate the exact depth of the tear site to plan additional procedures if needed. In patients with PTRCT treated by debridement, 89% had good or excellent outcomes at minimum 5 years follow up.[40] In another study[41] addressing elite overhead throwers, most of patients could return to competitive professional pitching after debridement. However, 55% of patients could return to their previous level of competitive sports.

Acromioplasty

When clinical signs or subacromial osteophytes suggestive of subacromial impingement are found after sufficient bursectomy, acromioplasty can be done for bursal sided PTRCT. The purpose of this technique is to remove osteophytes, flatten the acromion undersurface and clear the subacromial space for the rotator cuff to glide. Satisfactory results in 15 out of 16 patients with bursal sided PTRCT treated by acromioplasty in 5 years follow up have been reported.[42] The exact role of acromioplasty is not clear as no significant difference in outcomes have been described between arthroscopic bursectomy alone and arthroscopic bursectomy with acromioplasty.[43]

Acromioplasty with Debridement

A study comparing the bursectomy alone with bursectomy and acromioplasty in PTRCT patient described satisfactory results in 84% patients with no significant difference in results between the two procedures.[16] Weber[44] presented results of study comparing open acromioplasty and repair with arthroscopic acromioplasty and debridement for 65 patients with grade 3 of PTRCT. At 7 years follow, the mean UCLA scores in articular sided PTRCT was 31.6 for open repair group and 22.7 for arthroscopic debridement group, and for bursal sided PTRCT it was 33.0 and 13.6 respectively. It was concluded that grade 3 PTRCT should be treated with arthroscopic acromioplasty and repair. Park et al.[45] compared results of 13 patients with bursal sided PTRCT with that of 24 patients with articular sided PTRCT treated with acromioplasty and debridement. Although outcomes were better in patients with bursal sided PTRCT, there were no significant difference between groups, and both groups showed excellent results at 6 months postoperatively. Patients with grade 2 bursal sided PTRCT have shown higher failure rates (38%) than articular sided grade 2 of PTRCT (5%) when treated with acromioplasty and debridement at minimum 2 years follow up.[46] The outcomes of acromioplasty and debridement for athletes less than 40 years old are related with the cause of the tear and symptom period. Whereas, acute traumatic PTRCT of athletes showed good results in 86% patients, chronic PTRCT of athletes showed good results in only 66% patients.[47]

On the basis of the literature, grade 1 and grade 2 articular sided PTRCT can be treated by arthroscopic debridement alone, whereas grade 3 PTRCT should be repaired. For bursal sided PTRCT, only grade 1 PTRCT can be treated by debridement with or without acromioplasty, whereas grade 2 and grade 3 bursal sided tear should be repaired. As the effects of acromioplasty alone are not clear, it can be performed with debridement based on the morphology of acromion.

Repair

Repair of PTRCT is dependent on the depth of tear. Tear depth more than 50% of entire tendon thickness, grade 3 articular sided PTRCT and more than grade 2 of bursal sided PTRCT is considered as indications for repair. The indications for tear completion and repair technique are when the tear is almost through the complete tendon thickness with only a small remnant of tissue remaining after debridement and there is a tear on the corresponding side of the tear, that is, when a bursal surface tear is accompanied by an articular surface tear in the same tendon at the same location and vice versa. When the other side of tendon is intact and tendon viability at the tear site is relatively favorable, the transtendon repair technique for articular sided PTRCT[48] or small-window technique[49] for bursal-sided PTRCT are used.

Bursal Sided PTRCT

Traditionally for bursal sided PTRCT, tear completion and repair technique had been used. This technique in PTRCT showed significant improvement in the VAS and American Shoulder and Elbow Surgeons (ASES) scores in PTRCT.[47] The functional outcomes of tear completion and repair technique for bursal sided

PTRCT is comparable or superior when compared with that of articular sided PTRCT.[50] However, tear completion and repair technique damages the normal rotator cuff tissue, can alter the normal anatomy of footprint and cause tension mismatch. Yoo et al.[49] described small-window technique to help preserve the remnant rotator cuff tendon with minimum tissue damage for bursal sided PTRCT.

Surgical technique

Any repair technique for bursal-sided PTRCT (Fig. 4A) is to preserve the remaining tendon on the articular sided. After a conservative debridement, the flaps of torn tendon are defined. A small window is made in the articular sided tendon remnant. A suture anchor is inserted on the medial margin of the footprint. Sutures are then passed through the anterior and posterior flaps of the torn tendon remnant using a direct suture passing instrument. If the central portion of the torn portion is inadequate or does not come to the footprint, the suture is passed to include the intact tendon through the small window. This is done by passing the suture passing instrument through the same window. The sutures are then tied sequentially to reduce the torn edge to the footprint. Then lateral suture anchors are inserted to complete suture bridge technique (Fig. 4B).

Articular Sided PTRCT

1. Tear completion and repair technique in articular sided PTRCT

The tear completion and repair technique has shown satisfactory clinical outcomes and high levels of patient satisfaction. Good functional outcome and healing rates after arthroscopic repair using tear completion and repair technique for 41 patients with grade 3 PTRCT have been reported. At the final follow up, healed rotator cuff repair was seen in 88% patients on ultrasonography and 93% patients were satisfied with the results. The authors described that this technique allows better access to the tendon footprint and the removal of degenerative tissues.[47,51] However, this technique sacrifices the intact bursal sided rotator

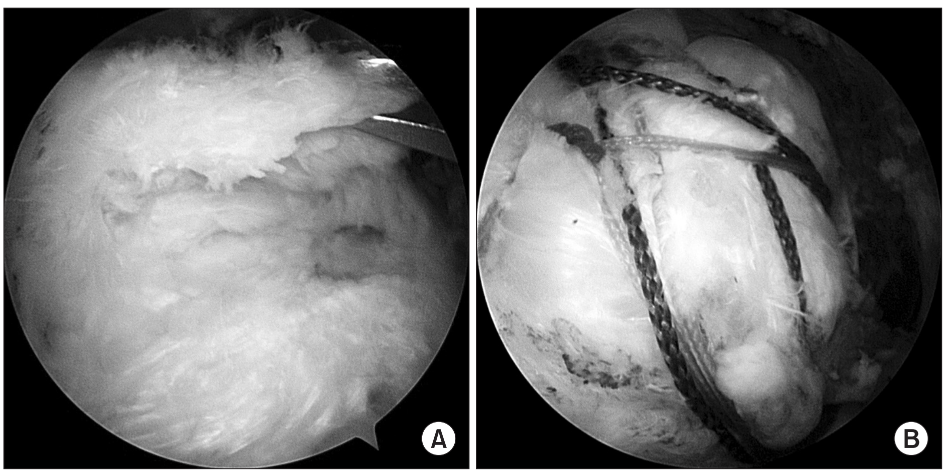

Fig. 4. (A) Bursal sided partial-thickness rotator cuff tear (PTRCT) as seen through the posterior portal. (B) Bursal sided PTRCT repaired by suture bridge technique.

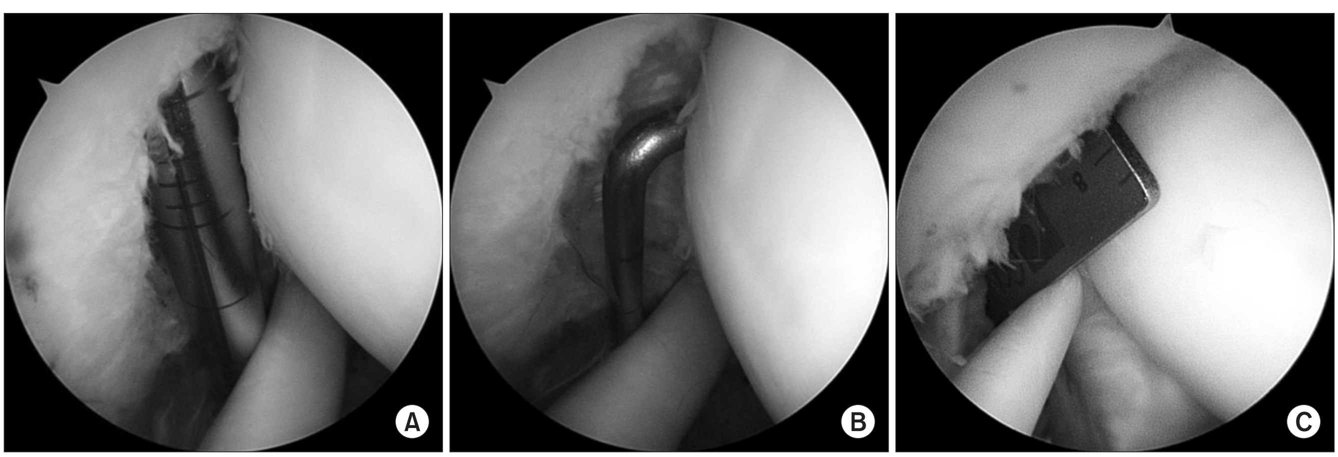

Fig. 5. Various methods to measure the depth of articular sided partial-thickness rotator cuff tear during the arthroscpic procedure. (A) Shaver tip. (B) Calibrated probe. (C) 90° angled ruler.

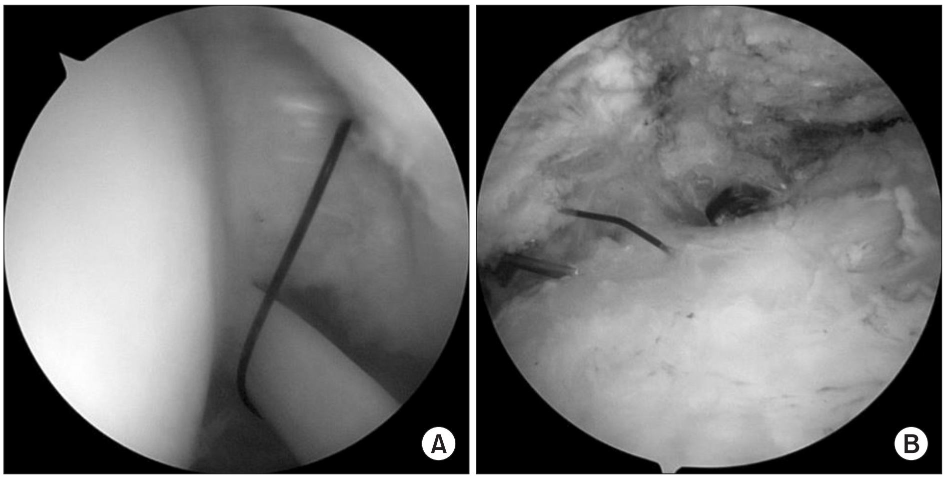

Fig. 6. (A) To locate the corresponding bursal sided cuff, a spinal needle is used to pass a no. 1 polydioxanone (PDS) suture as a marker. (B) After changing the position of arthroscope to the subacromial space, the corresponding bursal sided cuff which is marked with PDS suture can be identified.

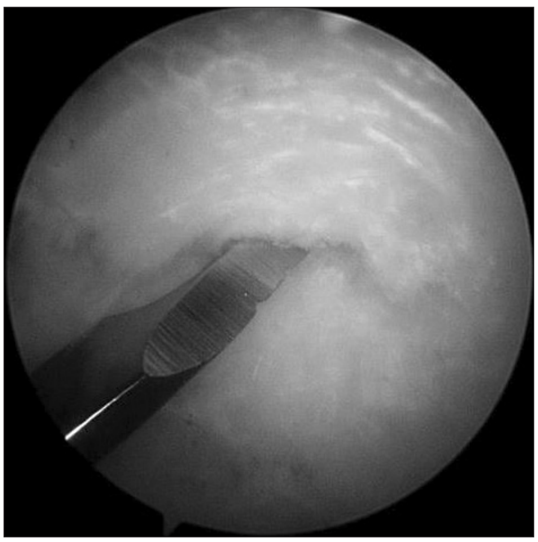

Fig. 7. Tear completion is accomplished using meniscal knife to preserve bursal sided tendon as much as possible.

cuff tendon and has the risks of non-anatomic restoration of the tendon footprint and of changing the normal biomechanics.

Surgical technique

When tear completion and repair technique is used for articular sided PTRCT, after careful debridement of the tear site, the depth of tear should be identified using a shaver (Fig. 5A), a calibrated probe (Fig. 5B) or a arthroscopic ruler (Fig. 5C). To locate the corresponding bursal sided cuff, a spinal needle is used to pass a no. 1 polydioxanone (PDS) suture as a marker (Fig. 6A). After changing the position of arthroscope to the subacromial space, the corresponding bursal sided cuff which is marked with PDS suture can be identified. (Fig. 6B). Tear completion is accomplished using meniscal knife (Fig. 7), shaver or arthroscopic punch. However, preservation of bursal sided tendon as much as possible is important to reduce retear rate. Thereafter conventional cuff repair technique using the suture anchor can be done.

2. Transtendon technique in articular sided PTRCT

Some prefer the transtendon repair technique, because using this technique the intact bursal sided of the tendon is preserved and the rotator cuff footprint is restored more anatomically. Recently, a long term study demonstrated significantly better functional and clinical outcomes with no complications using this technique.[52)]

In a prospective study, Shin[53)] compared clinical outcomes between patients treated using two different techniques and obtained satisfactory functional improvements and pain relief regardless of the repair technique. The tear completion and repair technique showed less postoperative morbidity, however tendon integrity after repair is of concern. On the other hand, the transtendon repair technique produced good tendon integrity after surgery; however, slower functional recovery was identified. In the transtendon repair technique, the restoration of retracted articular cuff layer on original footprint may cause bunching up of the bursal layer of the cuff and thus result in imbalance in tension. This non-physiologic tension may lead to residual shoulder discomfort[54)] or shoulder siffness.[55)] For these reasons, various modifications of transtendon repair techniques have been introduced to prevent tendon overstrain.[56-59)]

Surgical technique

After a conservative debridement the torn cuff edges and the footprint are defined. The arthroscope is placed in the glenohumeral joint through the posterior portal. A spinal needle is inserted percutaneously along the lateral edge of the acromion through the musculotendinous junction of the rotator cuff onto the lateral articular margin of the footprint. The spinal needle acts as a guide to locate the proper position of the suture anchor. Using a small skin incision, a suture anchor is inserted percutaneously across the rotator cuff tendon to the center of footprint parallel to the path of the spinal needle. If the size of the tear

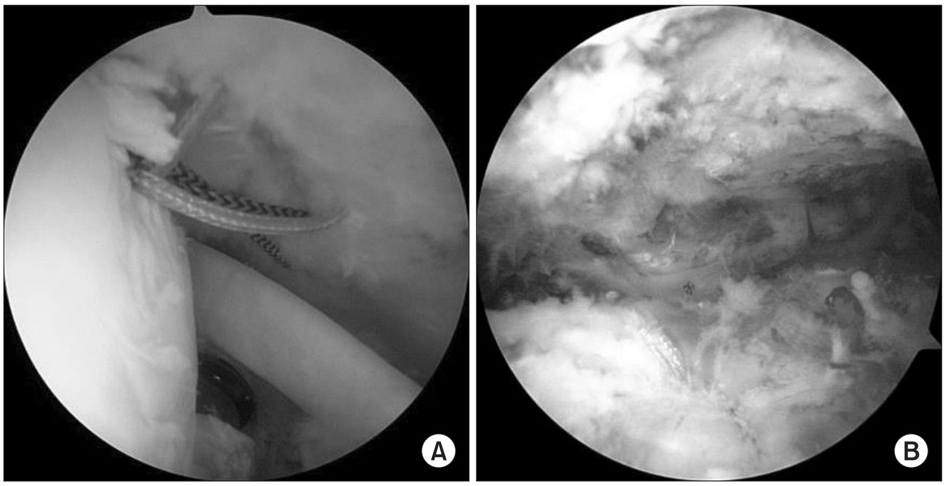

Fig. 8. Transtendon technique in articular sided partial-thickness rotator cuff tear. (A) The limb of the polydioxanone (PDS) suture which passed medial to the free edge of the torn tendon is pulled through the anterior portal. In subacromial space, the limb of the PDS suture penetrated the intact bursal sided cuff layer. The four suture limbs of the suture anchor substituted the PDS sutures by shuttle relay technique consecutively. (B) All the suture limbs of the suture anchor were tied on the bursal sided cuff surface.

is more than 1.5 cm, then two anchors are usually needed-one anteriorly and the other posteriorly. All the suture limbs are pulled through the anterior portal intra-articularly. A spinal needle is inserted percutaneously medial to the free edge of the torn tendon and a PDS suture is passed through the spinal needle to be retrieved through the anterior portal. Using the shuttle relay technique, the PDS suture is substituted for the suture limb of the suture anchor (Fig. 8A). Then the suture limb of the suture anchor which penetrated the rotator cuff can be seen outside of the skin through the puncture wound of the spinal needle. The same procedure can be repeated for the remaining suture limbs of the suture anchor from posterior to anterior. After changing the position of arthroscope to the subacromial space, all suture limbs in the subacromial space are retrieved through the lateral portal and tied on the bursal sided of the rotator cuff tendon to compress the torn edge of the tendon on the footprint (Fig. 8B).

Conclusions

PTRCT is not single disease entity but one phase of disease spectrum. Symptoms of PTRCT vary from being asymptomatic to severe pain leading to deterioration in quality of life. Pathogenesis of degenerative PTRCT is multifactorial. A detailed history, clinical examination and MR arthrography are used in the diagnosis of PTRCT. Treatment of PTRCT is chosen based on age, demands of patients, causes and depth of tear. In most patients, non-operative treatment should be initiated. Whereas debridement can be done for less than 6 mm of articular sided PTRCT and in less than 3 mm of bursal sided PTRCT, repair techniques are considered for higher grade PTRCT and who failed conservative treatment at least 3 months. Although the effect of acromioplasty is not clear, acromioplasty may be performed when the extrinsic causes appear to be the cause of tear. Either transtendon repair technique or repair after tear completion provides satisfactory clinical outcomes in treatment of articular sided PTRCT.

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