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Article *in* Techniques in Shoulder and Elbow Surgery · March 2019

DOI: 10.1097/BTE.0000000000000159

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Technique for a Novel Arthroscopic Transosseous Rotator Cuff Repair

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Abstract: The authors describe a novel all-arthroscopic anchorless transosseous suture technique that is easy to perform and reproduce and combines the benefits of both the arthroscopic technique and the transosseous approach. This procedure maximizes the tendon-footprint contact area obtaining both medial and lateral fixation without using any implanted device. In the current technical note, the procedure is described in detail providing several tips and tricks.

Key Words: rotator cuff, transosseous, arthroscopy, anchorless

(*Tech Should Elb Surg* 2019;20: 12–18)

For many years, open repair with transosseous (TO) sutures was considered the gold standard treatment for rotator cuff tears (RCT).

The advent of arthroscopy has revolutionized rotator cuff surgery, making arthroscopic rotator cuff repair the new gold standard. Claims in support of arthroscopic cuff repair include reduced invasivity and preservation of the deltoid muscle.[1,2] Materials and techniques have evolved over time in an attempt to improve the clinical results and optimize the repair. Technique evolution brought a shift from single row (SR) to double row (DR) and finally to transosseous equivalent DR. Anchors have evolved from a screw to impacted design to the latest all-suture anchors and with a continuous material evolution including titanium, resorbable, peek, and ultra high melecula weight poly-ethylene.

Despite this material and technique evolution, nonhealing or retear rates after arthroscopic rotator cuff repair are still significant and vary between 39% and 94%, depending on the number of tendons involved, the patient's age, and the tear size.[3,4]

In an interesting study, Kuroda et al[5] reported a retear incidence of only 6% in their series utilizing the TO approach, which is relatively small when compared with rates reported for suture anchors repair method.[6–9] Although there is no general consensus as to the causes of nonhealing, taking into account that biological factors are likely to play a major role, a potential limitation of the arthroscopic technique has been related to the use of suture anchors. A restoration of the original anatomy is associated with the original footprint coverage,[10,11] and several papers show the improvement of the geometrical parameters shifting from a SR to DR to transosseous equivalent DR to TO sutures.

Nevertheless, no final evidence of better clinical outcomes has been shown between SR and DR repairs,[12,13] and retear after a DR repair may lead to a medial failure whose management is complicated.[14]

Furthermore, the use of anchors has been associated with several complications including anchor pullout in case of poor bone quality and greater tuberosity bone osteolysis.[15] In addition to these issues, suture anchors are expensive, particularly if used in a DR or suture-bridge configuration, and may have limited efficacy in cases of revision wherein multiple anchors have previously been implanted into the tuberosity footprint or in the presence of poor bone quality.[5,16] In an attempt to overcome these limitations, all-arthroscopic anchorless TO suture repairs of the rotator cuff have recently been developed.[5,14,16,17]

Several studies have shown that TO tunnels provide excellent stability and that TO repairs are associated with a higher load to failure and yield less interface motion when compared with suture anchors.[18,19]

The authors describe a novel all-arthroscopic anchorless TO suture technique that is easy to perform and reproduce and combines the benefits of both the arthroscopic technique and the TO approach.

This procedure maximizes the tendon-footprint contact area obtaining both medial and lateral fixation without using any implanted device. In the current technical note, the procedure is described in detail, providing several tips and tricks.

Caldwell et al[20] measured an increase in the ultimate tensile strength (UTS) value when sutures were placed at sites more distal to the tip of the greater tuberosity or when the sutures were tied over a wider bone bridge.

They reported a 1.9 times UTS increase when sutures were tied on a plastic button augmentation (high-density suture button, Smith and Nephew, Memphis, TN). Increase of the mechanical response is proportional to cortical bone thickness, as sutures were placed more distally on the lateral aspect of the tuberosity.

In this study, they concluded that 10 mm from the tip and a bone bridge (measured in the anterior-posterior direction) of 10 mm are recommended values.

An interesting point concerning tuberosity integrity from this study showed that having 4 independent 4 mm holes does not influence fracture resistance or induce a humeral head collapse (with the proper distance between holes).

A trend of increasing UTS values was shown spanning from 10 to 30 mm in the proximal-distal direction and from 5 to 10 mm in the anteroposterior direction.

This same concept was supported by Gerber et al[21] describing a lateral polymeric augmentation in combination with a modified Mason-Allen stitch to further improve on traditional TO repair and to overtake limitations due to osteoporotic bone.

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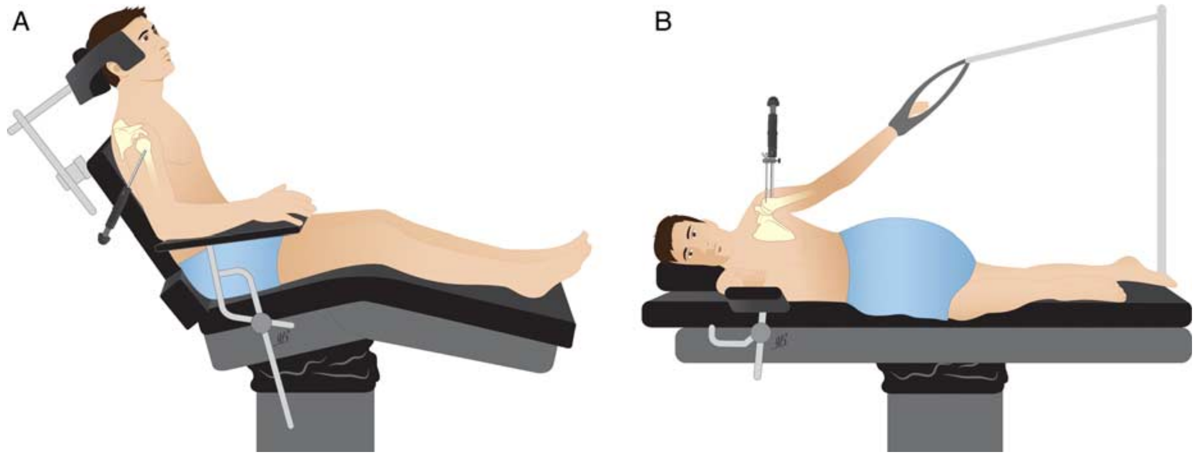

FIGURE 1. Taylor Stitcher orientation in beach-chair (A) and lateral decubitus (B) positions. full color online

The technique reported below was created to combine all the advantages of the TO approach. Several key factors can affect the stability and integrity of the repair, but, above all, the different technique requires several aspects to be considered to successfully accomplish the repair.

SURGICAL TECHNIQUE

The TO approach described here, performed with the Taylor Stitcher (TS) bone tunneler (NCS Lab Srl, Modena, Italy), can be used both on the beach-chair and lateral decubitus positions (as shown in Fig. 1).

The potential advantages of arthroscopic TO repairs include the associated decreased cost, elimination of suture anchors, and an improved efficiency in restoring the original rotator cuff footprint.

The potential disadvantages include increased surgical complexity, risk of fracture of the greater tuberosity, and suture cutout through bone (bone bridge collapse), which is a known limitation of the traditional open TO repair.

The procedure can be performed depending on anesthesiologist preference under general anesthesia or interscalene cervical plexus block or combined, in either beach-chair or lateral decubitus position, according to surgeon preference.

As visible in the below diagrams, the orientation of the instrument depends on the patient's position.

The optimal working area, as shown in Figure 2, the tunnel shape, and position can significantly affect the repair integrity, and the green area represents the optimal working area, whereas the external yellow bands indicate a too proximal and too distal positioning of the entry portal.

Keeping the lateral entry too proximal may provide an insufficient tunnel resistance and may lead to a tunnel collapse, while having the entry tunnel below the green area is beneficial in terms of bone quality (the UTS increases), but it may lead to

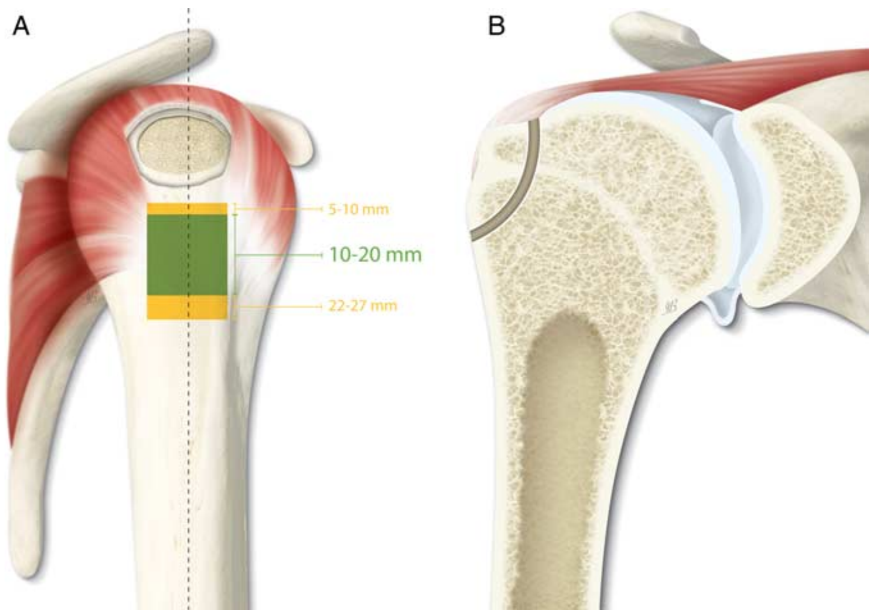

FIGURE 2. A, Definition of the optimal working area in the lateral aspect of the bigger tuberosity in a transosseous approach. B, The shape of the tunnel created by Taylor Stitcher in a transverse section.

FIGURE 3. Indicative distance between lateral portals.

an excessively long TO tunnel (the needle length is not enough to assure a correct exit in the footprint area).

Because of the lateral position of the entry point (optimal bone bridge dimension, as from Fig. 3, is in the range 15 to 20 mm), 2 separate portals are needed: one more proximal following the common indications and one shifted one finger distally.

An excessively elevated abduction angle in the lateral decubitus position can induce an over tilt of the instrument (too cranial orientation); hence, we do suggest keeping an optimal arm position below 15 degrees of abduction.

In a lying beach-chair position, the most important focus should be on keeping the TS perpendicular to the humeral head and lying in a plane parallel to the coronal plane.

The distal lateral portal is mandatory for instrument insertion while the more proximal, useful to get a better overall orientation, is facultative.

The lateral portal can be properly identified by using a spinal needle and checking with the scope. It is crucial (for a proper orientation) to keep the needle perpendicular to the humerus shaft. The recommended procedure consists of placing the needle parallel to the footprint in the lateral side, creating the incision, and marking with one finger the distance to the more distal portal (see Fig. 4: labels "1" and "2" represent, respectively, the more proximal and distal portals).

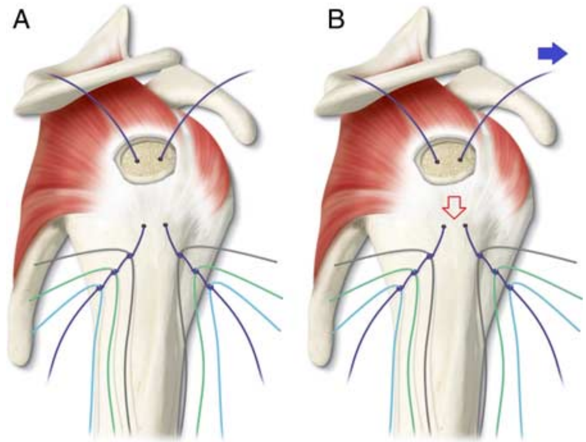

FIGURE 5. A, Sutures shuttled into transosseous tunnels. Multiple knots on the shuttle suture to better distribute suture volume. B, With the blue arrow, a correct pulling direction, in red, the wrong direction.

After tendon and bone preparation for suture (respectively, cutting and refreshing the torn tendinous edge and wide surface decortication), it is possible to prepare the 2 TO parallel tunnels required for this technique.

Once located, the lateral cortical entry point, a 1.9 mm entrance hole, is prepared anteriorly. The TS allows the creation of the TO tunnel by manually tapping the advancement mechanism in the handle to deploy the superelastic transosseus needle (STN). Tunnels are 1.9 mm in diameter and present a smooth curved morphology. Force to advance the needle and create the TO tunnel can vary significantly from patient to patient and can be tailored on the basis of bone quality. The authors suggest to start gently and, taking care of not being rejected by the bone, keep the TS firmly in contact with the bone.

The shuttle suture is then passed in 1 single step with the STN (having an eyelet close to the tip) through the TO tunnel, so that the sutures can be dragged through it. The targeted exit position in the footprint can be modified by changing the tilt angle as previously shown in Figure 4.

In case of moderate/large full-thickness RCT (C2-C3 Snyder classification), after the shuttle wire is passed through the TO tunnel, it is retrieved through the anterior portal and then

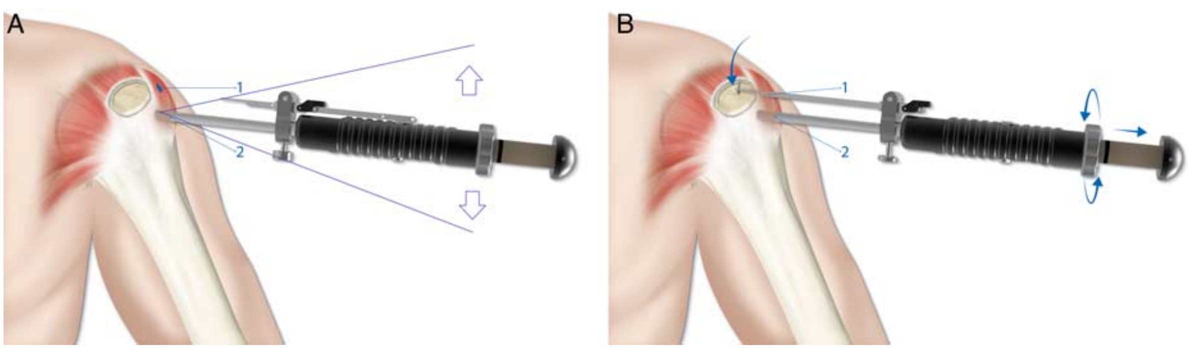

FIGURE 4. Proximal (1) and distal (2) portals (A) and deploying of the targeting frame (B). By changing the tilting angle (blue arrows), a change in the medio lateral exit point can be controlled.

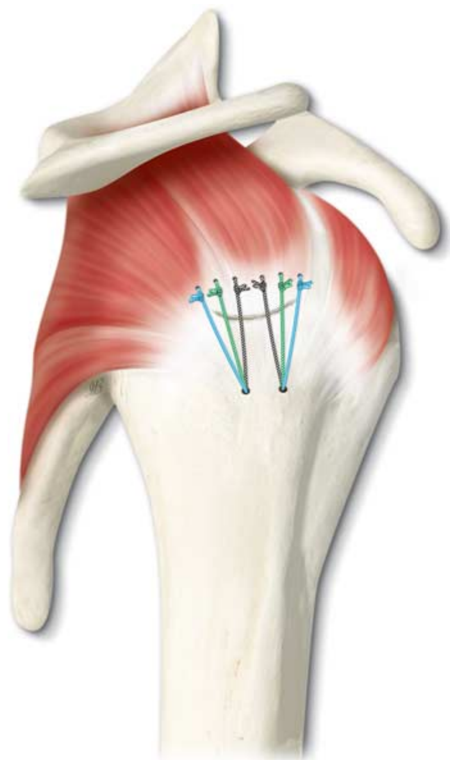

FIGURE 6. Final repair configuration with 2 separate transosseous tunnels.

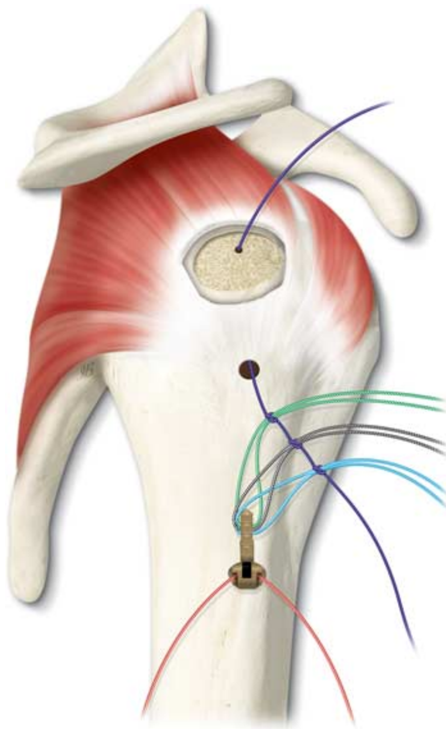

FIGURE 7. Shuttles connected with 3 separated sutures, each to be dragged into the transosseous tunnels.

passed through the medial portion of the tendon with different devices according to surgeon preference.

To optimally drag the sutures through the tunnel, the shuttle suture can be looped at one end and sutures can be easily pulled into the tunnel.

An alternative consists of tying the sutures to the shuttle. To avoid having an excessive drag force, create multiple knots and space these 10 cm apart (Fig. 5).

Attention should be paid to the pulling direction to avoid the shuttle breakage (Fig. 5). Sharp angle pulling directions should be avoided, and, when the drag force increases, consider alternating back and forth movements (oscillating) to loosen the sutures without increasing pull force.

All these steps can be skipped by directly loading sutures in the anterior eyelet of the STN. Up to 2 sutures can be directly passed in 1 step when creating the tunnel.

By increasing the number of sutures, the dragging and boring force increases accordingly.

The same procedure is repeated to prepare another TO tunnel posteriorly, leaving a minimum bone bridge of ∼10 mm between the 2 TO tunnels in the anteroposterior direction (Fig. 5). The 2 shuttle wires that have passed through the anterior and posterior TO tunnels are retrieved through the anterior portal. For each suture, one end is passed through the tendon, while the others exit on the lateral aspect of the tuberosity.

Before passing the sutures through the cuff, optimal tension and pull direction is assessed with the cuff for an optimal non-tensioned coverage. The knot tying sequence is carried out to properly restore the original coverage and limit tension on the cuff (more anatomic repair and reduced tension perform better, as reported by Milano et al[22]). The posterior to anterior sequence allows for a nontensioned repair configuration that avoids dog ears with an evenly compressed cuff reattachment (Fig. 6).

As a rule of thumb, keep the medial exit of the TO tunnel close to the cartilage surface (to maximize footprint).

Theoretically, there is no limitation in the number of sutures that can be shuttled into the TO tunnel, but on the basis of our experience, an optimal number is 3 (for each tunnel).

A similar configuration was reported by Garofalo and Castagna.[23]

TO repair performance can be influenced by: bone quality, geometry of the repair, number of sutures, shape of the tunnel, suture configuration, presence/absence of an augmentation device, specific contact area between sutures and bone, number of tunnels, and bone bridge extension.

When bone quality drops down below an acceptable threshold (not objectively well identified), the stability of the repair can be less reproducible and consistent (as evidenced by Mantovani and colleagues). In this paper, the authors describe how the repair performance can be better controlled with a tunnel augmentation system.

This technique is reported in 2 separate steps in Figures 7 and 8, in which one of the many possible configurations is presented.

The shuttle suture (eg, No1 monofilament suture, 4 metric) is connected by single knots to the sutures previously loaded into the implant frontal eyelet (Elite-spk, NCS Lab Srl, Carpi, Italy).

Sutures are pulled into the TO tunnel, and the implant is pushed (or slightly impacted depending on the bone quality), until the implant head has a steady cortical contact and a good stabilization.

Once the implant is in this position and sutures suspended on the inner eyelet (isolating these from a direct bone impingement) an endless number of configurations are possible.

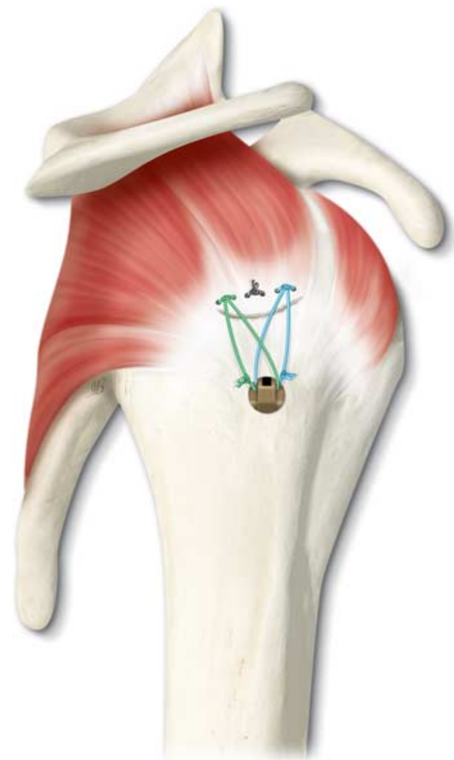

FIGURE 8. Final configuration with an augmentation device. Double-row–like construct with 1 implant only.

Figure 8 shows an example of a DR-like construct (with 1 implant only). This result can be realized by adding an additional shuttle in the external eyelet (eg, vicryl suture or monofilament).

Once the medial row is tied, instead of cutting the suture ends, one end of each suture is collected and brought together with one end of the shuttle in the lateral portal.

These are connected by simple knots and pulled through the lateral eyelet of the implant by pulling the anterior end of the shuttle.

It is important to have an optimal orientation of the shuttling force (we suggest to use the anterior portal to the shuttle having a vector oriented from distal to proximal and from lateral to anterior).

This direction preserves implant stability and does not displace or weaken the already stabilized construct (avoiding overtension).

The final configuration has the advantage of providing a very stable repair,[24] having an optimal footprint coverage and compression at the bone-tendon interface.[25]

A variant of the previously described pure TO approach by using a top-down approach is described below. With this approach, main differences are in portal positioning.

Portals are described in Figure 9.

Posterior portal (A)—palpate the soft spot created by the glenoid medially, the humeral head laterally, and the rotator cuff superiorly.

Anterosuperolateral portal (b)—1 cm lateral to the anterolateral corner of the acromion, frontal to the AC joint.

Lateral portal (B)—4 cm lateral to the acromion in line with the posterior aspect of the clavicle. This portal will create a parallel access to the footprint area.

Draw an equilateral triangle at the base of the lateral edge of the acromion as from Figure 9.

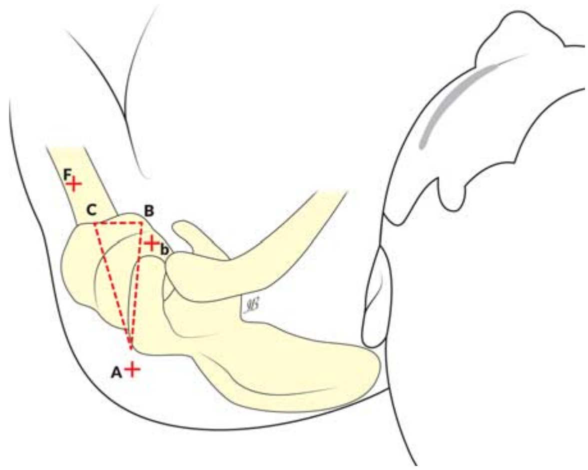

FIGURE 9. Portal positions in the reverted approach. full color online

Portal F—in line with b, 3 fingers distally. Use this portal for the cannula to retrieve sutures.

Recommended portal to tie the knots is in line with B but two fingers distally. Use this portal to tie knots.

Before inserting, check for the lateral aspect of the tuberosity. A working volume on the side is needed for a clear view and management of the sutures (place the shoulder in 20 to 30 degrees of abduction and 15 to 20 degrees of forward flexion) (Fig. 10).

Use a needle to identify the superior anteromedial portal (b), frontal to the AC joint, to ascertain the long axis of the humeral shaft and, simultaneously, to be as perpendicular as possible to the supraspinatus footprint and close to the cartilage.

Insert the instrument's main cannula of the TS through the above-mentioned portal (superior anteromedial) and align it with the diaphysis (humeral shaft and long axis of the device must be as parallel as possible).

Prepare to deploy the needle by gently taping on the posterior part of the piston until the STN tip emerges in the lateral aspect of the tuberosity at 15 to 20 mm distally. Be careful to keep guide in contact with the bone avoiding being rejected and displaced during STN deployment.

Once the STN needle emerges on the lateral side, slightly turn the gray knob to retrieve the STN needle, and fold the shuttle. Grab the shuttle with a grasper by entering a distal and lateral portal (F) and completely retract the STN needle in the stainless steel cannula (by turning the knob clockwise). Tighten knots from the distal and lateral portal (P) to prevent any bone cutting.

The number of tunnels and sutures deployed depends on the lesion type, tear size, grade of retraction, elasticity of the tissues, quality of the tissues, and the type of repair configuration.

REHABILITATION PROTOCOL

After surgery, the shoulder is immobilized for 4 weeks using a brace, applying 15 degrees of abduction and neutral rotation. During this 4-week period, only passive exercises with abduction and forward flexion are allowed. From 4 weeks onward, full range of motion is recommended stepwise, starting with active exercises aimed toward strengthening the rotator cuff and deltoid muscle.

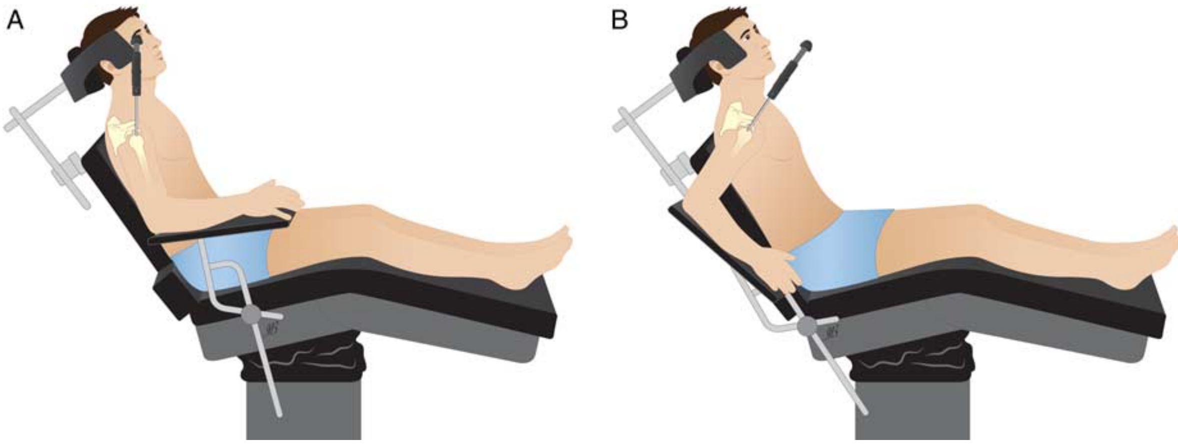

FIGURE 10. A, Orientation of the arm to have better access to the footprint area. B, With the extension of the arm, a better access to the posterior part of the cuff is obtained. full color online

CONCLUSIONS

The improvement of the suture technique in RCT has permitted a considerable increase in the possibility of a successful treatment of this pathology. Nevertheless, the complication of relapses remains.

With regard to the TO arthroscopic technique, Kuroda et al[5] reported a retear rate of 6% at 24 months, and Flanagin et al[26] reported a 3.7% failure rate at 38 months. Randelli et al[27] reported that an overall retear rate at a mean follow-up of 15 months was 13%, with 11% of these cases being minor discontinuities, and only 2% being medium to large, full-thickness lesions.

In a first series, Baudi et al[28] reported a very encouraging result in terms of retear incidence based on the technological principles described above.

A second case series is presented by Chillemi et al,[29] with a pure TO approach, passing a unique suture tape into 2 parallel tunnels (8-shape technique). The authors reported that the use of the TS eliminates all these possible complications. The entry point on the lateral cortex of the humerus avoids any conflicts with the acromion. In addition, the TO tunnels are created in a smooth and gradual manner, avoiding any risk of fracture.

In their experience, the 8-shape technique presents several advantages over the published techniques, as it does not require any fixation device or cannula, and only 1 suture tape is used, avoiding the risk of suture twist and decreasing the operative time.

As reported by Randelli and colleagues TO repair was found to be associated with faster pain reduction. Overall, the TO technique seems to offer results similar to those provided by SR anchor repair in arthroscopic rotator cuff repair.

Additional advantages of a TO approach are associated to an easier treatment in case of revision and overall cost reduction of the procedure.

Dyrna et al[30] measured in a cadaveric test set up the performance provided by this TO approach with a revision simulated specimen. They demonstrated an equivalent repair strength in comparison with a primary fixation and, furthermore, a large footprint contact (compared with an SR fixation with screwed anchors).

About the former, it is important to consider the absence of hardware in the footprint area, the elimination of a dangerous migration, and the more anatomic repair. All these factors together reduce the invasivity and increase the probability of the healing process, offering, moreover, a better environment and a better scenario in case of recidivation.

In conclusion, the described technique, is a viable solution applicable to any type of rotator cuff lesion, as reported by the case series, and that seems to be very well performing in a revision environment, as from laboratory base set up.

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