The "Parachute" Technique: A Simple and Effective Single-Row Procedure to Achieve an Increased Contact Area Between the Cuff-Tendon and Its Footprint

Luis Natera, M.D., Paolo Consigliere, M.D., Caroline Witney-Lagen, M.D., F.R.C.S., Juan Brugera, M.D., Ph.D., Giuseppe Sforza, M.D., M.Ch.(Orth), Ehud Atoun, M.D., and Ofer Levy, M.D., M.Ch.(Orth), F.R.C.S.

Abstract: Many techniques of arthroscopic rotator cuff repair have been described. No significant differences in clinical outcomes or rerupture rates have been observed when comparing single-row with double-row methods. Not all single- and double-row repairs are the same. The details of the technique used are crucial. It has been shown that the suture-tendon interface is the weakest point of the reconstruction. Therefore, the biomechanical properties of rotator cuff repairs might be influenced more by the suture configuration than by the number of anchors or by the number of rows involved. Techniques that secure less amount of tendon over a smaller area of the healing zone might be expected to have higher failure rates. The way the sutures of the "parachute technique" are configured represents a quadruple mattress that increases the contact and pressure between the tendon and its footprint and increases the primary load to failure of the repair. We present a simple and effective single-row technique that involves the biomechanical and biological advantages related to the increased contact area and pressure between the cuff and its footprint.

Many techniques of arthroscopic rotator cuff repair have been described. No significant differences in clinical outcomes or rerupture rates have been observed when comparing single- to double-row methods.[1] Not all single- and double-row repairs are the same. Single-row methods might not restore the rotator cuff footprint but do provide a good functional outcome. The details of the technique used are crucial.[2]

From the Reading Shoulder Unit, Royal Berkshire Hospital and Berkshire Independent Hospital Reading (L.N., P.C., C.W-L., J.B., G.S., O.L.), Berkshire, United Kingdom; Hospital San Juan de Dios Pamplona (J.B.), Pamplona (Navarra), Spain; and Ben-Gurion University, Barzilai Medical Center Campus (E.A.), Ashkelon, Israel.

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Address correspondence to Ofer Levy, M.D., M.Ch.(Orth), F.R.C.S., Reading Shoulder Unit, Royal Berkshire Hospital and Berkshire Independent Hospital Reading, Berkshire RG1 6UZ, United Kingdom. E-mail: oferlevy@readingshoulderunit.com

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It has been shown that the suture-tendon interface is the weakest point of the reconstruction.[3] Therefore, the biomechanical properties of rotator cuff repairs might be influenced more by the suture configuration rather than by the number of anchors or by the number of rows involved.

From the moment a rotator cuff tear is repaired, there is a race between the sustained strength of the repair construct and the tendon healing time. If the strength of the construct is poor, the tendon repair is more likely to fail before healing. Techniques that secure less amount of tendon over a smaller area of the healing zone might be expected to have higher failure rates.[4]

In a human cadaveric model, single-row rotator cuff repair using a modified suture configuration could achieve comparable results in cyclic displacement and ultimate load to failure when compared with double-row suture-bridge repair.[3] Moreover, it has been shown that single-row reconstructions using modified suture configurations may restore the anatomic footprint coverage and optimize the tendon-bone interface until the cuff heals biologically to the footprint.[3] Furthermore, it has been postulated that a single-row repair may be sufficient for rotator cuff tears that do not involve the entire footprint.[3]

We present a simple single-row technique that involves the biomechanical and biological advantages related to an increased contact area and contact pressure between the cuff tendon and its footprint. The way sutures of the parachute technique are configured represents a quadruple mattress configuration resembling a parachute that increases the primary load to failure of the repair, as well as the contact area and the contact pressure between the tendon and its footprint. Other advantages of this procedure include a lower cost, and reduced difficulty in case of need for revision surgery as a result of the small numbers of suture anchors.[5]

Surgical Technique

Patient Positioning and Portals

The technique can be performed with the patient either in the lateral decubitus or the beach chair position (Video 1). General anesthesia preferably with interscalene block is used. If the lateral decubitus position is used, a longitudinal traction of 3 kg is applied with the arm abducted to 20° to 30° of abduction and neutral flexion. A standard posterior portal is established for assessment of the glenohumeral joint. The usual portals are posterior, lateral, and anterior; additional lateral portals can be created as needed. The posterior and lateral portals are usually used for viewing. All the portals can be used as working portals.

The Parachute Technique Stages

1. Cuff-Tear Assessment

The configuration, size, and elasticity of the rotator cuff tear are assessed using the suture manipulator, both from the joint side and the bursal side. The surgeon should have a clear idea of the best way to reconstruct the rotator cuff. This technique has been conceived for full-thickness tears as well as for PASTA (partial articular supraspinatus tendon avulsion) lesions. For PASTA lesions, we recommend an all-inside glenohumeral joint and transtendon repair.

2. Arthroscopic Subacromial Decompression

The lateral portal is made in line with the posterior border of the acromioclavicular joint (ACJ), 3 fingerbreadths distal to the lateral border of the acromion. We tend to use the Helicut Burr (Dyonics, Smith & Nephew, Andover, MA) both for soft tissue and bone, but if the bursa is very thick, a 3.5-mm full-radius blade (Dyonics, Smith & Nephew) can be used at the beginning. First of all, with the scope pointing toward the cuff, the posterior veil of the bursa should be removed to guarantee a proper view. Afterwards, the view of the scope is changed toward the acromion, the posterior limit of the impingement lesion is marked, and all the soft tissue should be removed from that limit, toward the anterior aspect of the acromion. Once the acromion is completely free of soft tissue, we remove 4 mm of the anterior acromial spur, always from lateral to medial and from anterior to posterior. Once the most medial aspect of the acromion has been reached (limit with the ACJ), we flatten the central ridge created, until we get a completely regular bony surface showing only cancellous bone.

3. ACJ Excision Arthroplasty (If Indicated)

Once we have finished with the subacromial decompression, we start cleaning the soft tissue and bursa located underneath the distal clavicle, until we clearly identify the ACJ. Then we move the burr to the anterior portal and remove 4 mm of bone from each side of the ACJ. It must be mentioned that special attention should be paid to the clavicle cortical bone that is located in its anterior and superior aspects. This cortical bone is often hidden behind the soft tissue (acromioclavicular ligaments and intra-articular disc), and if it is not properly removed may represent a source of residual ACJ pain. To gain better access to the superior border of the distal clavicle, the assistant could press the distal clavicle down. This gesture will show more clearly the superior cortical bone that may be hidden behind soft tissue. Similarly, the surgeon must pay special attention to the magnitude of acromial resection in the posterior aspect of the ACJ. An insufficient resection at this level may also represent one of the causes for possible failure and residual pain. A good way to achieve better access to this area is to ask the assistant to pull the elbow backward. This gesture will open the ACJ space and make it easier to work. It should also be mentioned that the superior acromioclavicular ligament should be carefully preserved to avoid subsequent ACJ instability.

4. Arthroscopic Release of the Rotator Cuff

Debridement of the tear edges, release, and mobilization of the cuff is performed. Arthroscopic release of the rotator cuff is performed as needed, both from the joint side and the bursal side. The radiofrequency probe can be used for this stage. The rotator cuff should be released circumferentially from the base of the coracoid and the scapular spine on the bursal side, and circumferentially around the glenoid from the joint side. Caution should be exercised when releasing not to damage the nerves that pass medially.

5. Parachute Technique Rotator Cuff Repair

The parachute technique can be performed best with the arthroscope intra-articular in the glenohumeral joint from the posterior portal. The working portals are the lateral and anterior ones. However, in cases of full-thickness tears it can be performed with the arthroscope in the lateral portal, and the anterior and posterior portals are working portals.

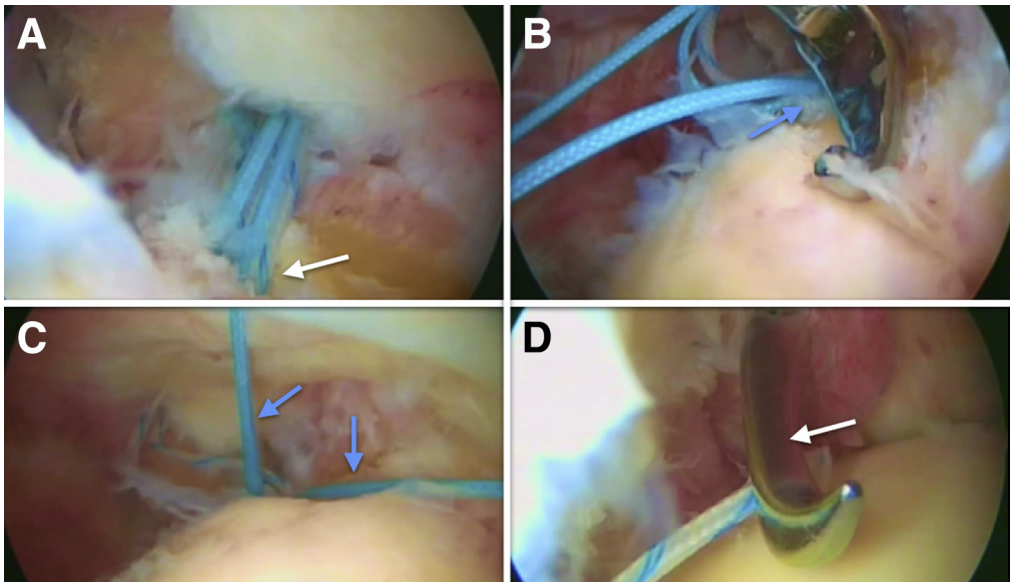

Fig 1. Arthroscopic view from the posterior portal of a right shoulder with the scope located in the articular aspect of the tear. (A) The sutures are seen emerging from the anchor (white arrow) that has been previously placed on the footprint at the greater tuberosity. This is a double suture-loaded anchor that has been inserted into the area of the footprint to achieve the best reconstruction of the rotator cuff repair. In this C-shaped tear, the anchor was placed at the center of the C, just adjacent to the articular cartilage. (B) Once the anchor has been placed, one of the sutures of the double suture-loaded anchor (in this case the blue sutures, blue arrow) are placed posteriorly by means of the suture manipulator. (C) Once both the posterior sutures of the double suture-loaded anchor have been placed posteriorly (in this case, the blue sutures, as pointed out by the blue arrows) and have penetrated the cuff tissue, by means of the Sixters, the divergent direction of these sutures can be observed. (D) The Sixters (white arrow) can be observed once the cuff tissue is penetrated and one of the limbs of the anterior suture (the most lateral one) is grabbed.

Intra-articular All-Inside Technique

The advantage of using an intra-articular all-inside technique is that any lamination of the tendon can be assessed and all the layers of the rotator cuff can be easily defined and repaired. The sutures are passed through the tendon to restore the rotator cuff cable back to the footprint.

6. Preparation of the Footprint on the Tuberosity

The footprint on the greater tuberosity is prepared with a burr to achieve some bleeding from the surface but without compromising the cortical bone. This is usually performed while viewing through a posterior intra-articular portal and inserting the shaver blade either through the anterior portal or an accessory superolateral portal.

7. Anchor Placement

A double suture-loaded anchor is inserted into the area of the footprint to achieve the best reconstruction of the rotator cuff repair (Fig 1A). In a C-shaped tear, this will be in the center of the C, just adjacent to the articular cartilage. In an L-shaped tear, the anchor will be placed opposite the apex of the L adjacent to the articular cartilage to achieve the best reconstruction of the rotator cuff. Any double-loaded anchor can be used.

8. Passage of the Suture Through the Cuff Tissue

With the arthroscope inside the glenohumeral joint, the suture limbs are prepared, pushed, and parked into the joint sequentially using the suture manipulator (Fig 1B)—1 limb at a time, the 2 limbs of one suture posteriorly and the other 2 limbs of the other suture anteriorly. The penetrating graspers (Sixters; Tag Medical, Ga'aton, Israel) are passed from the subacromial bursa into the joint in a blind manner using triangulation skills and the surgeon's 3-dimensional knowledge and perception of the shoulder (Fig 1C). The 2 limbs of each suture are passed through the healthy edge of the tear (Fig 1D and 2A), incorporating any lamination and all layers of the tendon posteriorly and anteriorly, creating a configuration of a horizontal mattress suture (Fig 2B and Video 1) anteriorly and posteriorly.

In case of large, full-thickness tears, this technique can be performed with the arthroscope in the lateral portal as well: After completion of steps 1 to 8 as described, the arthroscope is transferred to the lateral portal for viewing, and the posterior and anterior portals are used as working portals. The suture limbs are

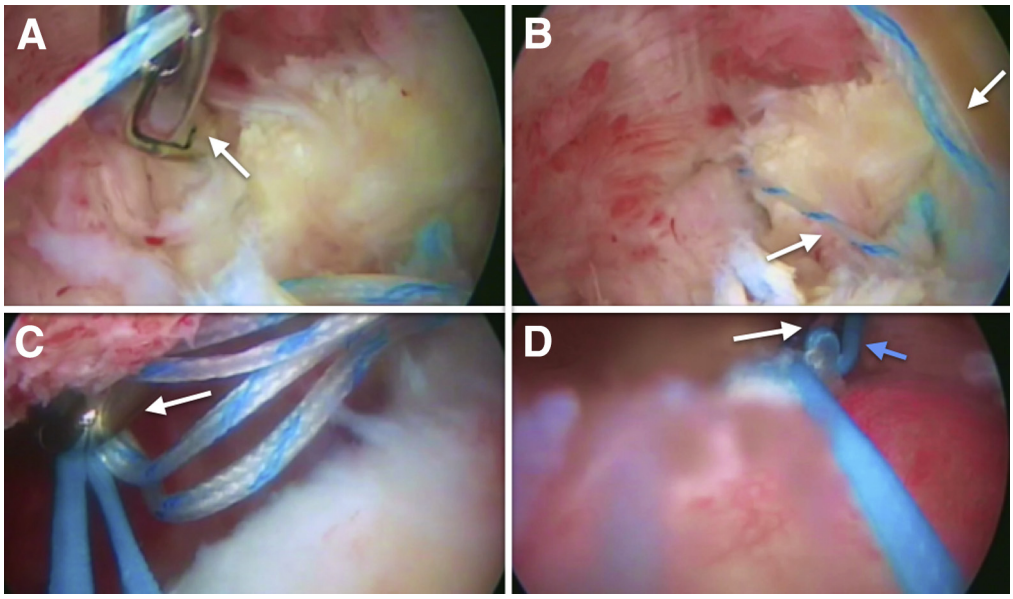

Fig 2. Arthroscopic view from the posterior portal of a right shoulder with the scope located in the articular aspect of the tear. (A) The Sixters (white arrow) can be observed once the cuff tissue is penetrated and one of the limbs of the anterior suture (the most medial one) is grabbed. (B) The anterior sutures can be seen emerging from the anchor in a divergent direction before passing through the cuff tissue (white arrows). (C) The suture manipulator (white arrow) is seen grabbing all suture limbs from the portal that are going to be used for knot tying, to avoid soft tissue interposition. (D) The final aspect of the cuff repair by means of the parachute technique can be observed. Notice that the trailing ends of each mattress sutures are tied to each other with simple knots (posterior to anterior and vice versa, blue arrow and white arrow, respectively).

prepared, pushed, and parked into the joint sequentially using the suture manipulator—1 limb at a time, the 2 limbs of one suture posteriorly and the other 2 limbs of the other suture anteriorly. The Sixters are passed from the subacromial bursa into the joint and each suture is passed through the healthy edge of the tear, incorporating any lamination and all layers of the tendon posteriorly and anteriorly creating a configuration of 2 horizontal mattress sutures, 1 anteriorly and 1 posteriorly.

9. Knot Tying and Parachute Configuration

The 2 limbs of each suture are tied between them, using a nonsliding knot, creating a configuration of 2 horizontal mattress sutures, 1 anteriorly and 1 posteriorly. At the time of the knot tying, the traction is released and the patient's arm is abducted, to relieve the tension from the rotator cuff while the sutures are tied up.

To increase the contact area and contact pressure between tendon and bone, the trailing ends of each mattress sutures are tied to each other with simple knots (posterior to anterior and vice versa). To achieve that, all the trailing ends of the sutures are brought out together through the most medial portal available (usually the anterior portal) using the suture manipulator. All sutures limbs should be grabbed by the suture manipulator from the portal that is going to be used for knot tying (Fig 2C) to avoid soft tissue interposition. They are tied with one knot placed posteriorly and the other anteriorly, to avoid crowding of the knots.

This configuration creates better approximation of the cuff surface to the footprint and not only "spot welding" (Fig 2D). This technique consists of a suture and knot configuration that resembles a parachute (Fig 3), thereby increasing the contact area and pressure between the cuff and its footprint with only single-row repair.

If a pathology of the long head of the biceps, tenosynovitis, or lesion of its pulley is found, a long head of the biceps tenodesis or tenotomy is performed as well. In Table 1, the pearls, pitfalls, risks, key points, indications, and contraindications of the technique have been listed.

Addition of a Second-Row Repair if Needed

For larger tears, or after a repair with the parachute technique as a medial row, where there is a flap of cuff tissue laterally, a double-row technique in a ratchet-loop configuration is recommended.[5] In this technique, a second double suture-loaded anchor is placed laterally. One pair of sutures is used for the anterior leaf of the tear and the other pair for the posterior leaf. Using a penetrating grasper, the suture is taken through the cuff, creating a loop of suture that is left out through the cuff. The free end of the same suture limb, which

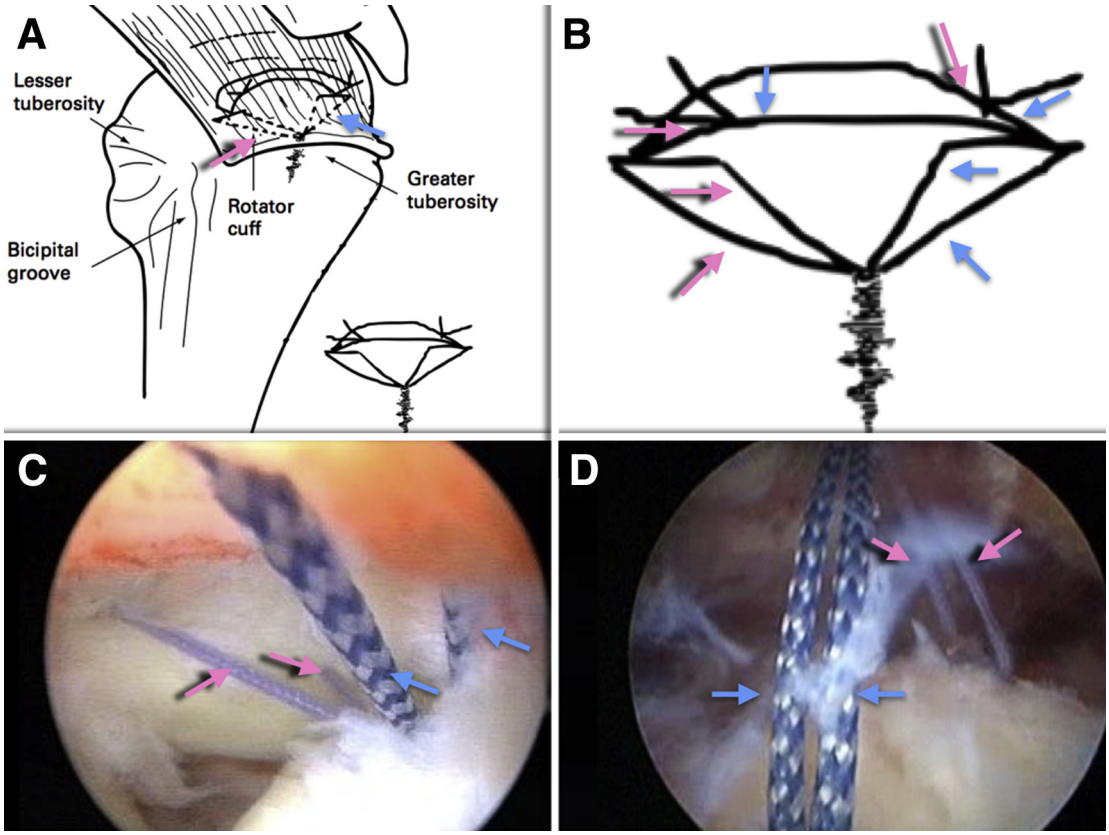

Fig 3. (A) Illustration of the suture configuration of the parachute technique. The blue arrow is pointing toward the posterior sutures, and the purple arrow is pointing toward the anterior sutures. Observe that to increase the contact area between the tendon and bone, the trailing ends of each mattress suture have been tied to each other, resembling the structure of a parachute. Reproduced with permission and copyright © of the British Editorial Society of Bone and Joint Surgery.[5] (B) Illustration of the suture configuration of the parachute technique. The blue arrows are pointing toward the posterior sutures, and the purple arrows are pointing toward the anterior sutures. Observe that once the mattress sutures have been configured and thus sutures tied (blue to blue, and purple to purple), one of the posterior sutures (blue arrow) is tied to one of the anterior sutures (purple arrow) and vice versa. Reproduced with permission and copyright © of the British Editorial Society of Bone and Joint Surgery. (C) Arthroscopic view from the posterior portal of a right shoulder with the scope located in the articular aspect of the tear, showing the sutures emerging from the anchor in a divergent direction before passing through the cuff tissue. The blue arrows are pointing at the posterior sutures, and the purple arrows are pointing at the anterior sutures. (D) Arthroscopic view from the posterior portal of a right shoulder with the scope located in the acromial aspect of the tear, showing the sutures emerging from the cuff (one limb anterior and the other limb posterior) before meeting each other to be knotted and then configure the superior aspect of the parachute. Again, the blue arrows are pointing at the posterior sutures, and the purple arrows are pointing at the anterior sutures.

has been passed through the cuff, is then passed through the loop. It is then tied to the limb of the suture that has not been passed through the cuff using a nonsliding knot, creating a ratchet-loop (pulley) configuration. The procedure is repeated for the posterior leaf of the cuff.

Rehabilitation

Postoperatively, the arm is immobilized in a sling with a small pillow that holds the arm in neutral rotation and mild abduction. In this position, the tension on the repaired cuff is reduced. The sling is used for 6 weeks. During this period, only passive movements are allowed, consisting of a pendulum and passive-assisted exercises, depending on the size of the tear and intraoperative findings. Six weeks after operation, active movements are gradually incorporated, progressing to resistive and strengthening exercises. Physiotherapy and hydrotherapy continue for up to 6 months after operation, based on the progress of each patient.

Discussion

The parachute technique is expected to increase the contact area and contact pressure between the inferior layer of the repaired rotator cuff tendon and the footprint, and to achieve coaptation between the delaminated acromial and articular layers. The initial fixation achieved with this technique may minimize

Table 1. Pearls, Pitfalls, Risks, Key Points, Indications, and Contraindications of the Technique

- Diagnostic glenohumeral arthroscopy should be the first step of the procedure - Assessment of the articular side of the cuff is important to properly see any delamination of the tear - When making PASTA (partial articular supraspinatus tendon avulsion) repairs, it is important to locate the right place for anchor fixation by means of using a spinal needle, before splitting between the fibers and penetrating the remaining cuff with the shaver blade and the suture anchor - It is important to have a clear view that all the torn cuff layers are repaired; this is assisted by performing the all-inside repair	Pearls
- Orthopaedic surgeons who are not fully familiarized with arthroscopic techniques may have problems with orientation of the anatomy and the 3-dimensional perception of the shoulder - Tissue passage with the Sixters should be delicate, to avoid damage to the cuff - The surgeon should test the strength of the anchor fixation by means of pulling the sutures - Surgeons must be aware of the risk of tissue shearing when making sliding knots	Pitfalls and risks
- This procedure is a simple and effective single-row technique, which involves the biomechanical and biological advantages related to an increased contact area and contact pressure between the cuff tendon and its footprint - Other advantages of this procedure include lower cost and less difficulty of revision surgery because of small numbers of suture anchors - This technique is expected to achieve coaptation between the delaminated acromial and articular layers of the torn cuff - When making cuff repairs with the Sixters, penetration and suture retrieval are easier and faster	Key points
- Small to medium-sized C-shaped tears - Joint-side partial-thickness tears (PASTA lesions) - For larger tears, or after a repair where there is a remaining flap of cuff tissue laterally, a double-row technique with the parachute technique as medial row and a ratchet-loop configuration as the lateral row	Indications
- None - Any contraindication for rotator cuff repair	Contraindications

the recurrence of retears and might increase the probability of biological fixation of the cuff to its footprint.

It has been postulated that by increasing the footprint area of repair, there may be an increased rate of tendon healing over the bone, which may have an impact on the clinical outcome.[6] Mazzocca et al.[7] have shown in a biomechanical study performed in cadaveric rotator cuffs repaired via either single-row fixation or via 3 different methods of double-row fixation that there were no differences between groups in regard to the cyclic displacement and load to failure, despite the theoretical restoration of the anatomic footprint achieved by double-row methods. White et al.[8] assessed the strength of different types of suture configurations and found no significant differences between groups, supporting the idea that the simplest form of fixation should be considered when performing these repairs. Taking in consideration all the evidence available, we advocate use of the "parachute technique," which is a simple, reproducible, and effective procedure that increases the contact area and pressure between the cuff tendon and its footprint.

Delamination is a commonly observed finding at the time of rotator cuff repair,[9,10] and clinical studies have reported it as a negative prognostic factor in rotator cuff healing.[11] The repair of delaminated tears is more complex than that of nondelaminated tears, mainly because the margin of the inferior (articular-side) layer is usually more retracted than that of the superior (bursal-side) layer.[12] We believe that a proper fixation of the inferior layer, as performed with our all-inside parachute technique with articular-side visualization of the cuff during repair, would involve more probabilities of tendon healing, with associated improved clinical outcomes. The parachute technique is expected to achieve coaptation between the delaminated acromial and articular layers.

It has been shown that comparable biomechanical results can be expected when comparing a modified single-row rotator cuff reconstruction versus a suture-bridging double-row repair.[13] Castagna et al.[14] developed a single-row repair technique that consisted of a triple-loaded suture anchor using a modified Mason-Allen suture repair. They affirmed that the Alex stitch, which is a combination of a central horizontal mattress and 2 bridging simple suture loops, represents a good alternative in arthroscopic rotator cuff repair. The parachute technique achieves a horizontal mattress by means of a simple single-row procedure, similar to that of the Alex stitch.

It also has been postulated that by "spreading" the repair over a larger area, the 3-dimensional footprint is more accurately restored.[4] The theoretical biomechanical advantages of a double-row repair, which theoretically may reduce retear rates when compared with single-row techniques, have shown not to correlate with an improved functional outcome within a 12-month period of follow-up.[15] Functional outcomes of single- and double-row procedures are so far equivalent.[2]

Before considering the use of the parachute technique, the surgeon must be really aware of the type of tear that is going to be treated. This technique has been conceived for small to medium-sized C-shaped tears and for joint-side partial-thickness tears (PASTA lesions). For larger tears, or after a repair where there is a remaining flap of cuff tissue laterally, we recommend the use of a double-row technique, with the parachute technique as medial row, and a ratchet-loop configuration as the lateral row. It should be mentioned that tissue passage with the Sixters should be delicate, to avoid damage to the cuff.

The parachute technique for rotator cuff repair represents a simple and effective single-row technique, which involves biomechanical and biological advantages. The way the sutures of this technique are configured increases the contact area and pressure between the tendon and its footprint and the primary load to failure of the repair. This represents a procedure that potentially involves a lower cost, as well as less difficulty in case of revision surgery as a result of the small numbers of suture anchors.

References

1. Burks RT, Crim J, Brown N, Fink B, Greis PE. A prospective randomized clinical trial comparing arthroscopic single- and double-row rotator cuff repair: Magnetic resonance imaging and early clinical evaluation. *Am J Sports Med* 2009;37:674-682.
2. Reardon DJ, Maffulli N. Clinical evidence shows no difference between single- and double-row repair for rotator cuff tears. *Arthroscopy* 2007;23:670-673.
3. Lorbach O, Bachelier F, Vees J, Kohn D, Pape D. Cyclic loading of rotator cuff reconstructions: Single-row repair with modified suture configurations versus double-row repair. *Am J Sports Med* 2008;36:1504-1510.
4. Cole BJ, ElAttrache NS, Anbari A. Arthroscopic rotator cuff repairs: An anatomic and biomechanical rationale for different suture-anchor repair configurations. *Arthroscopy* 2007;23:662-669.
5. Levy O, Venkateswaran B, Even T, Ravenscroft M, Copeland S. Mid-term clinical and sonographic outcome of arthroscopic repair of the rotator cuff. *J Bone Joint Surg Br* 2008;90:1341-1347.
6. Lo IK, Burkhart SS. Double-row arthroscopic rotator cuff repair: Re-establishing the footprint of the rotator cuff. *Arthroscopy* 2003;19:1035-1042.
7. Mazzocca AD, Millet PJ, Guanche CA, Santangelo SA, Arciero RA. Arthroscopic single-row versus double-row suture anchor rotator cuff repair. *Am J Sports Med* 2005;33:1861-1868.
8. White CD, Bunker TD, Hooper RM. The strength of suture configurations in arthroscopic rotator cuff repair. *Arthroscopy* 2006;22:837-841.
9. Mori D, Funakoshi N, Yamashita F. Arthroscopic lamina-specific double-row fixation for large delaminated rotator cuff tears. *Arthrosc Tech* 2014;3:e667-e671. eCollection 2014.
10. Han Y, Shin JH, Seok CW, Lee CH, Kim SH. Is posterior delamination in arthroscopic rotator cuff repair hidden to the posterior viewing portal? *Arthroscopy* 2013;29:1740-1747.
11. Frurin PH, Landreau P, Gregory T, et al. Cuff integrity after arthroscopic rotator cuff repair: Correlation with clinical results in 576 cases. *Arthroscopy* 2007;23:340-346.
12. Sugaya H, Maeda K, Matsuki K, Moriishi J. Functional and structural outcome after arthroscopic full-thickness rotator cuff repair: Single-row versus dual-row fixation. *Arthroscopy* 2005;21:1307-1316.
13. Lorbach O, Kieb M, Raber F, Busch LC, Kohn D, Pape D. Comparable biomechanical results for a modified single-row rotator cuff reconstruction using triple-loaded suture anchors versus a suture-bridging double-row repair. *Arthroscopy* 2012;28:178-187.
14. Castagna A, Garofalo R, Conti M, Borroni M, Snyder SJ. Arthroscopic rotator cuff repair using a triple-loaded suture anchor and a modified Mason-Allen technique (Alex stitch). *Arthroscopy* 2007;23:440-444.
15. Anderson K, Boothby M, Aschenbrener D, van Holsbeeck M. Outcome and structural integrity after arthroscopic rotator cuff repair using 2 rows of fixation (minimum 2-year follow-up). *Am J Sports Med* 2006;34:1899-1905.