Robotic-Assisted Latissimus Dorsi Transfers Around the Shoulder

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KEYWORDS

• Robot surgery • Robotic surgery • Accessory nerve injury • Tendon transfers • Scapular dyskinesia • Irreparable rotator cuff lesion • Rotator cuff lesion • Subscapularis lesion

KEY POINTS

- Robotic-assisted latissimus dorsi tendon transfers provide precision, minimal soft-tissue trauma, reduced bleeding and superior cosmetic outcomes.
- Technique uses DaVinci robot with specific portals and CO2 insufflation for LD harvesting, protecting neurovascular structures during transfers.
- Limitations of the procedure include longer operative time and small sample size.
- LD tendon harvested robotically , transferred via mini-open approaches, fixed with anchors or transosseous sutures.

Video content accompanies this article at http://www.orthopedic.theclinics.com.

INTRODUCTION

Robotic-assisted surgery, a well-established practice in modern medicine, has gained increasing prominence across various surgical specialties due to its advantages over traditional techniques.[1] This innovative approach has been applied in orthopedics, particularly in procedures such as brachial plexus repair, nerve release,[2–4] and microsurgery.[5–7]

The integration of robotics with endoscopy represents a significant advancement, enabling faster patient recovery, shorter hospital stays, and promoting minimally invasive surgical techniques.[8] The benefits of robotic-assisted surgery are extensive, including highly precise movement control, improved access to the operative field, and 3-dimensional visualization that enhances depth perception. Smaller incisions and an expanded range of motion allow surgeons to perform more complex maneuvers.[9] Additional advantages include tremor filtration, motion scaling, hands-free camera control, and reduced postoperative complications.[10,11]

In shoulder pathologies that require latissimus dorsi (LD) tendon transfer, traditional harvesting techniques often involve extensive soft-tissue dissection, which can lead to trauma, infection, and visible scarring. Robotic surgery offers a minimally invasive alternative that may reduce rehabilitation time and limit soft-tissue adhesions.[12–16]

Conventional large surgical approaches using retractors under tension may injure deeper muscular and neurovascular structures.[17] In contrast, minimally invasive robotic procedures have been shown to result in fewer adhesions, a decreased need for revision surgeries, and shorter courses of physical therapy, while also proving cost-effective.[14,16]

In shoulder surgery specifically, robotic assistance has improved the identification of key anatomic structures such as the quadrangular space, the axillary and radial nerves, and the LD muscle—all critical elements in some tendon

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Abbreviation	
LD	latissimus dorsi

transfers around the shoulder.[4,12–14] This approach allows for precise nerve identification, reduced bleeding, and enhanced motion accuracy through tremor filtration and motion scaling, significantly advancing the field and confirming the feasibility of robotic surgery in reducing intraoperative complications.[13]

This communication aims to present the techniques and results for robotic harvesting and transfers of the LD as new frontier in robotics for shoulder surgery.

METHODS

Between January 2017 and November 2023, 21 LD tendon transfers were performed robotically.

Three orthopedic conditions used the robotic transfers of the LD.

a. Lesion of the accessory nerve with consequent impairment of the Trapezius muscle. The LD effectively mimics lower trapezius function, as the intact rhomboid major retains its scapular retraction and elevation role, producing a combined force vector with the transferred LD that closely replicates the lower trapezius.[14] Miniopen techniques allow levator scapulae and rhomboid minor transfers (mimicking upper and middle trapezius posttransfer) (Fig. 1).[14] This procedure represents 12 cases.
b. Posterosuperior rotator cuff massive lesion. This procedure represents 6 cases.
c. Subscapularis irreparable lesion. This procedure represents 3 cases.

Clinical evaluation of the patients used the UCLA Shoulder Score and VAS, recorded preoperatively and at a minimum of 6 months after surgery.

Surgical Technique

The patient is positioned in a dorsolateral decubitus position with a 30° tilt. The arm is maintained at 90° abduction and external rotation using a Trimano support system (Arthrex, Naples, FL).

The anterior border of the LD muscle is identified by palpation, and its anatomic landmarks are drawn on the skin, including a central line marking. A 1 cm initial incision is made 10 cm distal to the axilla, serving as the central portal. Because there are no natural cavities in this

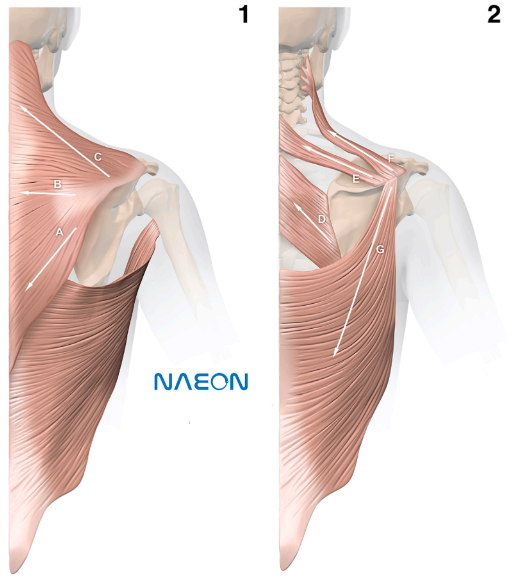

Fig. 1. 1. Original trapezius vector diagram: (A) Lower trapezius, (B) Middle trapezius, (C) Upper trapezius. 2. Vector diagram of the transfers, mimicking the trapezius's original vectors: (D) The major rhomboid remains in its original position to assist with scapular retraction, (E) The minor rhomboid takes the place of the middle trapezius, (F) The levator scapulae takes the place of the upper trapezius, (G) The LD takes the place of the lower trapezius. (*From* Garcia JC Jr, Torres MC, Fadel MS, et al. Robotic Transfer of the Latissimus Dorsi Associated With Levator Scapulae and Rhomboid Minor Mini-Open Transfers for Trapezium Palsy. Arthrosc Tech. 2020;9(11):e1721–e1726.)

region, digital dissection followed by Allis-assisted dissection is performed to create a space over the tendon, leading to its bony insertion. This cavity is carefully formed beneath the radial nerve and other neurovascular structures until the bone and the biceps tendon are palpated.

A central portal (CP) is established 10 cm from the axilla. Two additional portals are created: the medial portal (MP), located 7 cm medial and 7 cm from the axillary line on the thorax, and the axillary portal (AP), positioned 2 cm posterior to the CP line in the coronal plane, forming a triangular configuration. The DaVinci SI or Xi robot (Intuitive Surgical, Sunnyvale, CA), equipped with a 30° optic, is then inserted through the CP, allowing clear visualization of the LD tendon (Fig. 2). After the robot is docked, the robotic arms are introduced through the MP and AP into the preformed cavity. Depending on surgical needs, the 30° optic may be replaced with a 0° optic. Carbon dioxide insufflation is maintained at 8 to 14 mm Hg to

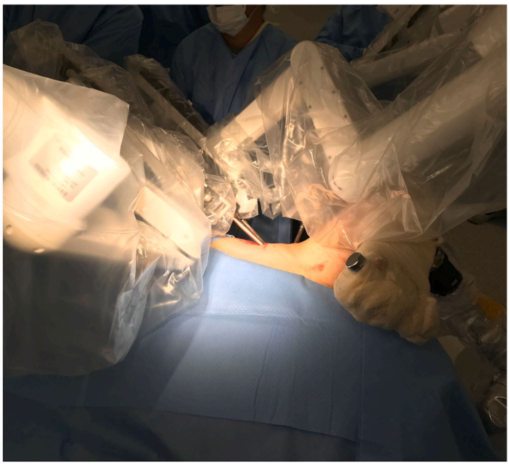

Fig. 2. Robot docking in axillary endoscopic robotic approach for LD access.

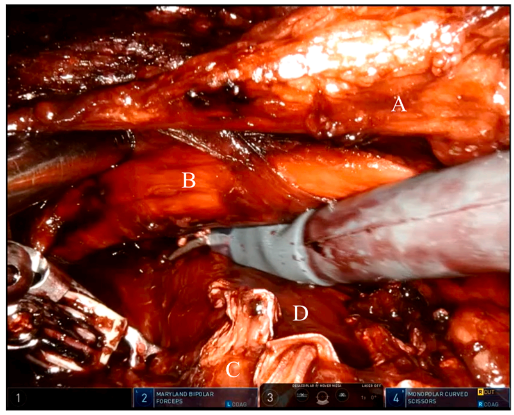

Fig. 4. Robotic endoscopic view: (A) Radial nerve, (B) Long head of the biceps, (C) LD tendon release, (D) Teres major.

ensure visibility and maneuverability within the surgical field.

The robotic arms are fitted with instruments specific to this procedure: a Maryland bipolar forceps and Hot Shears Monopolar Curved Scissors(Intuitive Surgical, Sunnyvale, CA). The third and fourth robotic arms are not used. The initial step involves clearing the camera's view to ensure optimal dissection. Next, the biceps tendon at the superior border of the LD muscle is identified (Fig. 3), along with its separation from the teres major muscle. Meticulous dissection along this plane distinguishes the tendinous fibers of the LD from the muscular fibers of the teres major, which facilitates visualization of the separation (Fig. 4).

Once the LD tendon is fully released, it is extracted through the optic portal using a Kocher clamp. If additional excursion is necessary, the portal can be enlarged for releasing the LD. The harvested tendon is then sutured using two No. 2 Maxibraid Sutures (Zimmer-Biomet, Warsaw, IN) (Fig. 5). Throughout the harvesting process, particular care is taken to avoid injuring the neurovascular pedicle of the LD.

After the Harvesting the LD tendon is passed through tunnels created by digital bunt dissection.

For lesion of the accessory nerve a subcutaneous dissection extends from the optics portal to fix the tendon at the scapular spine. Levator Scapulae and the Rhomboid Minor are also lateralized, to mimic the superior and middle Trapezius.

A 5 cm incision is made in the sagittal plane just above the superomedial border of the scapula, exposing the atrophic trapezius muscle, which is incised to access the underlying structures. Beneath the trapezius, the superomedial

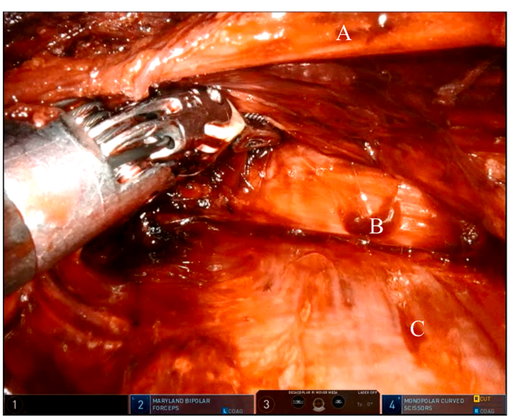

Fig. 3. Robotic endoscopic view: (A) Radial nerve, (B) Long head of the biceps, (C) LD tendon.

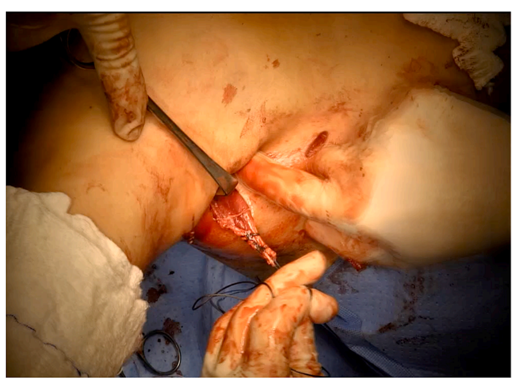

Fig. 5. Exteriorization of the LD through the widened optical portal.

border of the scapula and the levator scapulae muscle are identified, maintaining continuity with the rhomboid minor. The muscle fibers are separated based on their anatomic orientation, sometimes a small portion of the Rhomboid Major can come together with the Rhomboid Minor (Fig. 6). A small segment of scapular bone is preserved at the final position of the released levator scapulae and rhomboid minor tendons to facilitate healing.

All the muscle or most of the rhomboid major remains intact to preserve its function.

A 5 cm incision is then made in the axial plane above the scapular spine, medial to the original insertion point of the trapezius muscle. This incision exposes the scapular spine, allowing subcutaneous transfer of the LD to the inferior portion of the scapular spine to replicate the lower trapezius position (Fig. 7). Similarly, the levator scapulae and rhomboid minor tendons are transferred subcutaneously to the superior portion of the scapular spine (Fig. 8), aligning with the vectors of the upper and middle trapezius muscles (Figs. 9 and 10) (Video 1).[14]

Fixation is done by transosseous sutures in the scapular spine.

The post-operative cosmetic appearance of the robotic portals used for LD harvesting is shown in Fig. 11.

For posterosuperior rotator cuff massive lesion the harvesting of the LD follows the same steps as mentioned earlier. To transfer the tendon a lateral transdeltoid 3 to 4 cm mini approach is done. Using 1 finger through this approach and other in the central portal a subdeltoid path is done to reroute the tendon, inserting it at the posterolateral aspect of the humeral head. Fixation is done using 2 Quattro Link Knotless anchors (Zimmer-Biomet, Warsaw-USA). Patients need to present with no or minimal osteoarthritis.

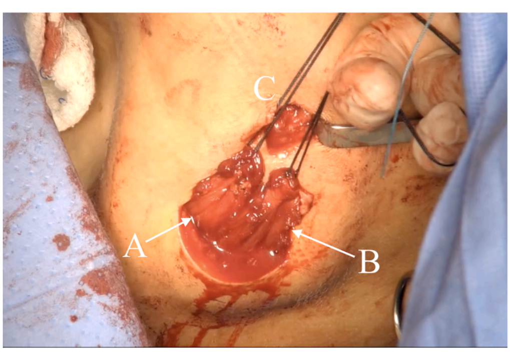

Fig. 6. (A) Levator Scapulae, (B) Rhomboid minor with a small portion of the proximal rhomboid major, (C) scapular spine approach.

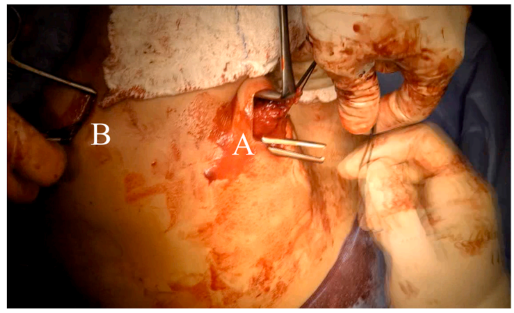

Fig. 7. (A) Widened optic portal, with the LD and the Kocher instrument.The Kocher instrument passes from the scapular spine approach (B) to the widened optic portal (A).

For subscapularis irreparable lesions the harvesting of the LD follows the same steps as mentioned earlier. To transfer the tendon a 3 to 4 cm deltopectoral approach is done over the subscapularis original insertion. Using one finger through this approach and other in the central portal a subdeltoid path is done. Care must be taken to avoid this path crosses over the radial nerve, it needs to be done under the nerve to avoid neurologic compression. The tendon is them rerouted, inserting it at the lesser tuberosity of the humerus. Fixation is done using two Quattro Link Knotless anchors (Zimmer-Biomet, Warsaw-USA). Patients need to present with no or minimal osteoarthritis and age less than 60-year old.

All patients included in this study presented more than 6 months follow-up.

Patients of the groups lesion of the accessory nerve and posterosuperior rotator cuff massive lesion were assessed using University of California Shoulder Rating (UCLA) and Visual Analog Scale of pain (VAS) before and 2 years after surgery.

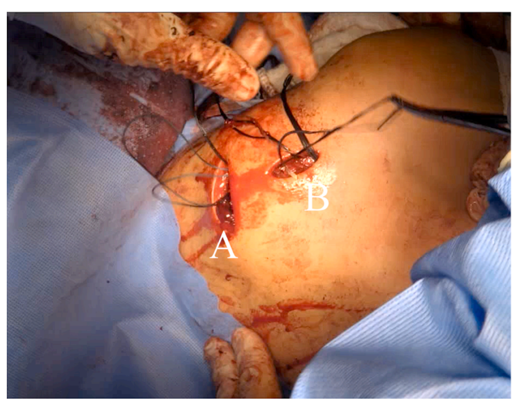

Fig. 8. (A) Superomedial border of the scapula approach, (B) Scapular spine approach.

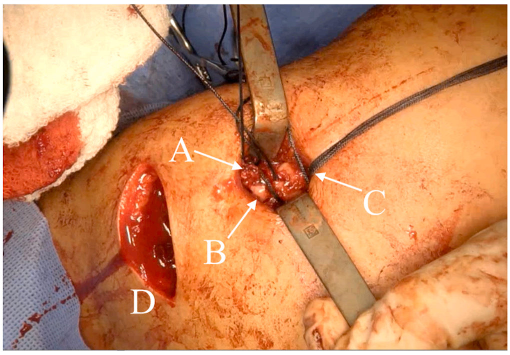

Fig. 9. (A) Levator scapulae, (B) Rhomboid minor, (C) wires of the LD, (D) superomedial border of the scapula approach.

Statistics were done according nature of the curves considering a $P<.05$ in a 2 tailed curve.

RESULTS

A total of 21 patients underwent surgical treatment and were evaluated Clinical improvements were observed in both pain and functional capacity across all surgical procedures.

Group Accessory Nerve Lesion

Twelve patients with accessory nerve lesions were assessed.

The VAS scores decreased from a preoperative mean of 3.75 $\pm$ 1.22 to 0.75 $\pm$ 0.46 postoperatively ($P<.01$), demonstrating a substantial reduction in perceived pain.

Similarly, UCLA Shoulder Scores improved from 22.33 $\pm$ 2.06 preoperatively to 32.50 $\pm$ 1.88 postoperatively ($P<.01$), indicating a marked enhancement in shoulder function.

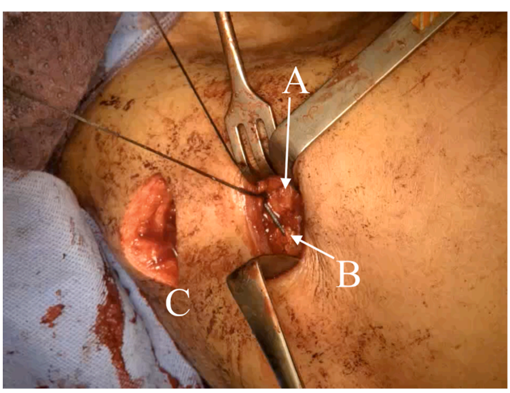

Fig. 10. (A) Scapular spine, (B) LD suture in the scapular spine, (C) superomedial border of the scapula approach.

Fig. 11. The postoperative cosmetic appearance of the robotic portals.

Because the postoperative data were not normally distributed, comparisons were performed using the Wilcoxon signed-rank test. The effect size was extremely large for both outcomes (Cohen's d = 2.66 for VAS and 3.69 for UCLA). Post hoc power analysis demonstrated exceptionally high statistical power (>99% for both variables), confirming the robustness of the findings despite the limited sample size. These results indicate that the sample was sufficient to detect clinically meaningful differences with high confidence, and further increases in sample size would be unlikely to alter the conclusions.

Group: Posterosuperior Rotator Cuff Massive Lesions

In patients with posterosuperior massive rotator cuff tears, VAS scores decreased from 5.17 $\pm$ 1.47 preoperatively to 1.00 $\pm$ 0.63 postoperatively ($P=.03$), indicating a significant reduction in pain.

Likewise, UCLA Shoulder Scores improved from 22.33 $\pm$ 2.06 to 32.50 $\pm$ 1.88 ($P=.03$), demonstrating considerable improvement in both shoulder function and pain relief.

However, the number of patients in this group remains limited, and additional data are required to confirm these preliminary findings.

Subscapularis Lesions

All patients with subscapularis lesions exhibited clinical improvement in both pain and UCLA scores. However, the sample size was too small to permit a statistical analysis.

Safety

No intraoperative or postoperative neurologic or vascular complications were observed.

Nevertheless, future studies involving larger and more diverse patient populations are warranted to better define the safety profile and potential risks of the procedure.

DISCUSSION

Traditional approaches for harvesting the LD often require large incisions, resulting in extensive scarring and suboptimal cosmetic outcomes. Insights gained from both cadaveric dissections and live surgeries have helped refine the principles and techniques of robotic LD harvesting.[4,12–16]

This procedure is indicated for patients with a formal need for LD transfer. Our current indications include

Spinal accessory nerve lesions leading to trapezius muscle palsy[14]; Massive posterosuperior rotator cuff tears in patients younger than 60 years with minimal or no glenohumeral osteoarthritis[12]; and

Irreparable subscapularis tears in shoulders with minimal or no osteoarthritis.[13]

Age plays an important role in LD transfer for posterosuperior rotator cuff tears. The LD, a native internal rotator, is rerouted to function as an external rotator, requiring cortical adaptation to a reversed vector of motion. In elderly patients, this neuromuscular reprogramming occurs more slowly, often leading to delayed functional recovery. For this reason, lower trapezius transfer tends to yields faster and more intuitive results in older individuals.

In contrast, for trapezius palsy and irreparable subscapularis lesions, the transfer axis and functional dynamics of the LD are synergistic with those of the original muscles, promoting a more intuitive and rapid adaptation.[14]

The trapezius muscle plays a central role in scapular kinematics, and its dysfunction significantly alters scapular rhythm, producing pain and mechanical imbalance. Patients commonly present with trapezius palsy and a characteristic dyskinesis of the scapular girdle. Although scapular winging may occur, it is usually less pronounced than in serratus anterior palsy.[14] Pain arises primarily from altered scapulothoracic joint mechanics. Ideal surgical candidates should demonstrate preserved function of the levator scapulae, rhomboid minor, and LD muscles.

Historically, treatments for trapezius palsy have involved extensive and invasive procedures.[18] Techniques using triple-tendon transfers,[19] have shown notable functional improvements but often yield unsatisfactory cosmetic outcomes.

The LD is a viable substitute for the lower trapezius,[14] as the rhomboid major remains anatomically intact, preserving its function as a strong scapular retractor and moderate elevator. The combined force vector generated by the transferred LD and the preserved rhomboid major closely reproduces the original lower trapezius vector. This synergistic alignment enables restoration of scapular depression, retraction, and rotational control.

Mini-open techniques allow the levator scapulae to function analogously to the upper trapezius after transfer, and the rhomboid minor to simulate the middle trapezius. The essential retraction and elevation vector of the rhomboid major remains unaffected.

The robotic transfer of the LD provides a less invasive alternative with significantly reduced scarring compared to conventional open methods. It also aligns more precisely with the force vector of the lower trapezius, providing effective scapular depression and retraction. The transferred LD's contribution to scapular rotation closely mirrors that of the native lower trapezius, enhancing dynamic stability throughout the range of shoulder elevation. At lower degrees of elevation, the scapula's instantaneous center of rotation lies medially, rendering the lower trapezius a depressor and downward rotator; as elevation increases, this center shifts laterally, transitioning the trapezius into an upward rotator.

For posterosuperior rotator cuff tears and irreparable subscapularis lesions, the literature consistently supports favorable outcomes with traditional LD transfer in well-selected patients.[20,21] The current study introduces a novel robotic technique for LD tendon harvesting, offering all the inherent benefits of minimally invasive surgery, such as reduced scarring, improved aesthetics, and decreased soft-tissue morbidity.

The robotic approach situates the incision slightly away from the axilla—an area prone to moisture, delayed healing, and infection, thereby improving wound management and cosmetic appearance. Furthermore, the method provides direct visualization and protection of the axillary and radial nerves, reducing the risk of iatrogenic injury commonly associated with deep dissection and traction during traditional open approaches.[17]

Robotic systems enhance precision through motion scaling and tremor filtration, reducing bleeding and intraoperative complications.[12–14] These advantages contribute to improved surgical control and may translate into more consistent outcomes.

Despite its benefits, robotic surgery presents certain limitations. The technology requires substantial investment in equipment, specialized instruments, and dedicated training. Although visualization and neurovascular management in robotic surgery are far superior to open procedures, manipulations of the LD muscle are not free of complications.

The number of patients is still limited, which reinforces the need for larger multicenter studies to validate the safety profile and refine the standards of the procedure.

Current operative times exceed those of conventional open techniques mostly related to the robot docking and creation of the cavity; however, ongoing technological advancements and increased surgeon experience are expected to enhance efficiency and reduce operative duration over time.

SUMMARY

The robotic-assisted transfer of the LD was feasible and yielded good results in this limited number of patients. It has the potential to become a valuable and reproducible option in the armamentarium of modern shoulder reconstructive surgery, aligning minimally invasive principles with precise surgical manipulation.

However, further studies with larger patient samples are recommended to gain a more detailed understanding of safety and to confirm these findings.

CLINICS CARE POINTS

- Robotic LD tendon transfer is feasible and safe for accessory nerve palsy, massive posterosuperiorcuff tears (age <60, minimal OA), and irreparable subscapularis tears.
- Precise robotic identification of axillary and radial nerves minimizes neurological risk.
- Select patients carefully : minimal glenohumeral osteoarthritis and good LD muscle function are essential.
- Avoid radial nerve compression during subscapularis transfer by routing tendon deep to the nerve.
- Maintain intact rhomboid major to preserve scapular retraction during trapezius reconstruction.

DISCLOSURE

JC Garcia is consultant of Zimmer-Biomet and Stryker.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocl.2026.03.002.

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