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ORIGINAL STUDY

Latissimus dorsi transfer using bone block technique to restore active external rotation in reversed total shoulder arthroplasty

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The aim was to compare the outcome of a reversed shoulder arthroplasty with a latissiumus dorsi transfer without (LD-BB) or with bone block (LD+BB) in patients with rotator cuff-deficient shoulders and combined loss of active elevation and external rotation. Postoperative patients with LD+BB were not immobilized compared to 6 weeks of immobilization in patients with LD-BB. Clinical outcome was evaluated using the Constant Score, ADLER score and satisfaction rate. Also radiological follow-up of the bone-block was performed. In total 29 patients (21 LD+BB, 8 LD-BB) were evaluated. There was no significant difference between both groups at 3 months, 6 months and 1 year in clinical outcome. The radiological evaluation revealed remodellation and ingrowth of the bone block in all but one patient. We conclude that the bone block procedure is a safe technique to perform a LD transfer with good clinical outcome. It also allows early mobilisation and radiological evaluation.

Keywords : Latissimus dorsi transfer ; reversed shoulder arthroplasty ; surgical technique ; bone block ; external rotation lag sign ; postoperative rehabilitation.

INTRODUCTION

Patients with massive rotator-cuff-insufficiency can be subdivided in three groups : isolated loss of elevation (pseudoparalysis of the shoulder), isolated loss of external rotation (ILER) or combined loss of active elevation and external rotation (CLEER).

For patients with a pseudoparalysis, a reversed shoulder arthroplasty can restore active elevation, although it is well known that an external rotational lag and the horizontal muscle imbalance of the shoulder cannot be restored by a reversed total shoulder arthroplasty *(1-3,10-12)*. Especially in those patients with CLEER, suffering from a posterosuperior rotator cuff insufficiency, with involvement of the teres minor (which provide 40% of the strength of external rotation *(3)*), there is no other muscle to provide active external rotation, and any attempt at shoulder elevation results in the forearm swinging toward neutral rotation (the Hornblower's sign). Daily activities are disturbed or become impossible because of the inability to control the spatial positioning of the arm, even worse while raising an object *(1)*. For this group a tendon transfer in combination with a reversed total shoulder arthroplasty may be indicated to restore active external rotation *(1-4,10-12)*.

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There are different techniques to perform this transfer. This difference can consist in how the tendon is released (without or with a sliver of bone to promote the healing) or to where the tendon is transferred *(5)*.

Gerber and colleagues described in 1988 a latissimus dorsi (LD) transfer using a two incision technique to restore active external rotation for irreparable posterior rotator cuff defects *(9)*, in 2007 he described the combined procedure with a reversed total shoulder arthroplasty also using a two incision technique with the insertion of the LD tendon to the facet of the infraspinatus *(7)*. Boileau and colleagues described a modified l'Episcopo technique (transfer of combined LD and teres major transfer) by using a single deltopectoral approach and attached the tendon transfer first to the stump of the pectoralis major muscle and in his modified technique to the posterolateral aspect of the greater tuberosity *(1-3,10)*. Both authors release the tendon from the bone. Ortmaier described in 2014 a technique with a bone sliver to promote good tendon integrity and lower tendon ruptures *(11)*. All authors proposed minimum 6 weeks immobilisation but different positions of immobilisation have been proposed.

We introduced a new surgical technique with a bone block. We hypothesized that a bone block, with the tendon attached to it, ensures better and faster healing of the transfer, lowers the risk of tendon ruptures and allows a earlier mobilisation

The aim of this study is to evaluate the short and long-term results of this new surgical technique using a bone block procedure for the LD transfer and no postoperative immobilisation compared with the modified l'Episcopo technique described by Boileau with 6 weeks postoperative immobilisation *(1-3)*.

MATERIALS AND METHODS

All patients with rotator cuff-deficient shoulders and combined loss of active elevation and external rotation that were treated with a reversed shoulder arthroplasty and a LD transfer in our department between 2007 and 2013 were evaluated. Inclusion criteria were a clinical external rotation lag sign or a Hornblower's sign, radiographic signs of rotator cuff arthropathy and an atrophy or fatty infiltration of the infraspinatus / teres minor muscles on pre-operative CT. All patients were pre-operative evaluated using the Constant Murley score.

Surgical technique

The same shoulder surgeon performed all the procedures. All the patients are positioned in the beach chair position with the affected arm draped free during the whole procedure. A classical deltopectoral approach is used, starting from the coracoids process and extending 10-12 cm distally parallel with the anterior border of the deltoid muscle. The cephalic vein is retracted laterally together with the deltoid muscle. Debridement of the subacromial space is performed and release of the bursal tissue and adhesions of the humeral head is performed. By evaluating the remaining rotator cuff a massive cuff tear of the supraspinatus and the absence of infraspinatus and teres minor is observed. Sometimes the teres minor is still present, but fully atrophied. The long head of the biceps is rarely identified in its groove, because it was frequently ruptured before. To prevent retraction, a biceps tenodesis at the level of the pectoralis major muscle is performed when the biceps is still present. For a better view en mobility the remaining rotator interval and jointcapsule is resected. The subscapularis is released but not detached from the lesser tuberosity.

Subsequently the humerus and the glenoid are prepared following the conventional technique to implant the reversed total shoulder arthroplasty (DeltaXtend-DePuy Synthes).In the modified l'Episcopo procedure, the technique described by Boileau et al *(1)* is used. (LD-BB) In the bone block procedure (LD+BB) following steps were used : Before implanting the humeral component the deltopectoral interval is extended distally to expose the whole pectoralis major tendon insertion at its crista on the humeral shaft (Figure 1). This tendon is released from its crista, and tagged with four Mason-Allan stitches (Ethibond Polyester Suture 2 - Ethicon) in which the long head of the biceps tendon is included. When the pectoralis major is reflected, the tendon of the latissimus dorsi can be

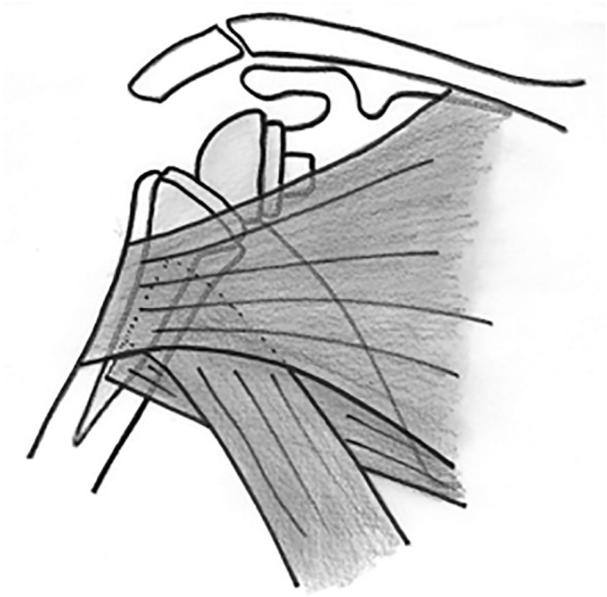


Figure 1. — Exposing the pectoralis major tendon insertion at its crista on the humeral shaft.

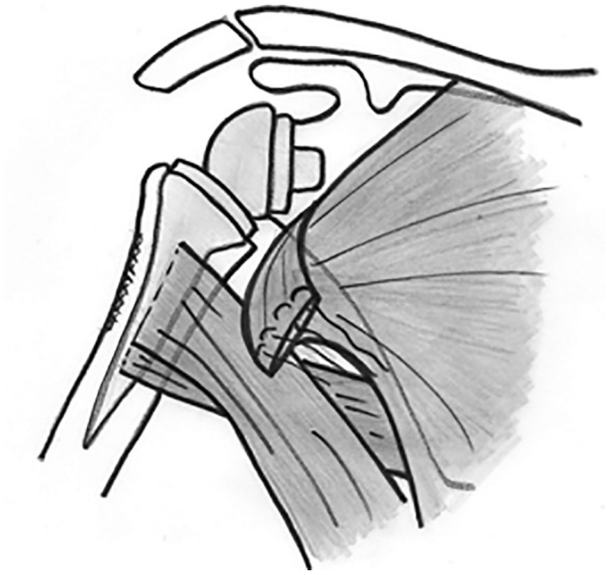


Figure 2. — When the pectoralis major is reflected, the tendon of the latissimus dorsi can be identified beneath.

identified beneath (Figure 2). Then the superior and inferior border are identified and released medially over a couple of centimeters. This release permits the identification of the humeral cortex posterior to the muscular insertion of the teres major tendon. Next, an osteotomy of the humerus is performed with a small oscillating saw. The osteotomy is directed to

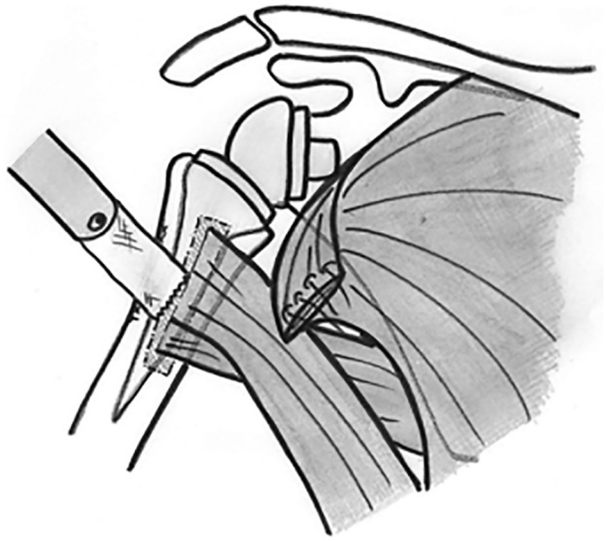


Figure 3. — The osteotomy of the bone block.

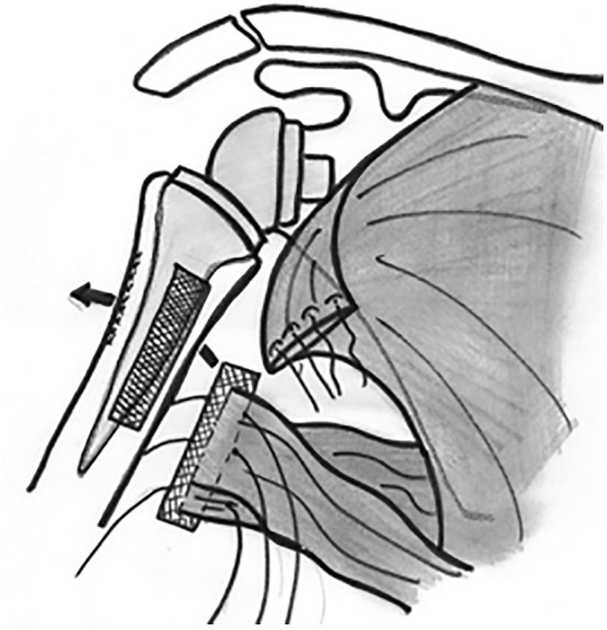


Figure 4. — Tagging the bone block.

the reamed centromedullary canal. One horizontal cut proximal and one distal to the latissimus dorsi tendon of approximally one centimeter is made, medial from the crista of the greater tubercle. Both lines are connected with a longitudinal osteotomy, situated at the medial side of the crista of the greater tubercle. To ensure a constant breaking of the osteotomy, a second small longitudinal osteotomy

(thus parallel with the long osteotomy line at the crista of the minor tubercle) of one centimeter proximally and distally to the latissimus dorsi attachement is performed (Figure 3). With a chisel the osteotomy is broken by a torsion manoeuvre. This permits to detach the combined insertion of the latissimus dorsi and the teres major attached to the bone block. This bone block is tagged with 4 thick nonabsorbable sutures (Ti-Cron 5, coated nonabsorbable polyester suture - Covidien) (Figure 4). Under gentle traction the tendons are carefully released while protecting the medially passing neurovascular bundle. To transfer the bone block all around the humeral shaft the posterior cortex of the humeral diaphysis must be released from all adhesions. This is performed by wrapping a moistened surgical swab around the posterior aspect of the humeral diaphysis. This creates a tunnel in which the bone block can now be transferred around the posterolateral aspect of the humerus at the same level of their insertion from medial to lateral. The sutures are then guided into the osteotomy window all around the humeral prosthetic stem (Figure 5). After placing the definitive humeral implant the bone block is placed in his window in a flipped manner and then sutured with the latissimus dorsi side into the humeral window as such that the outer cortex on which both tendons are attached can be firmly fixed to the humeral shaft. It is impossible the close completely the bony window because the teres major muscle and tendon is now more anteriorly situated than the latissimus dorsi, although the bone-to-bone cortical contact is always more than

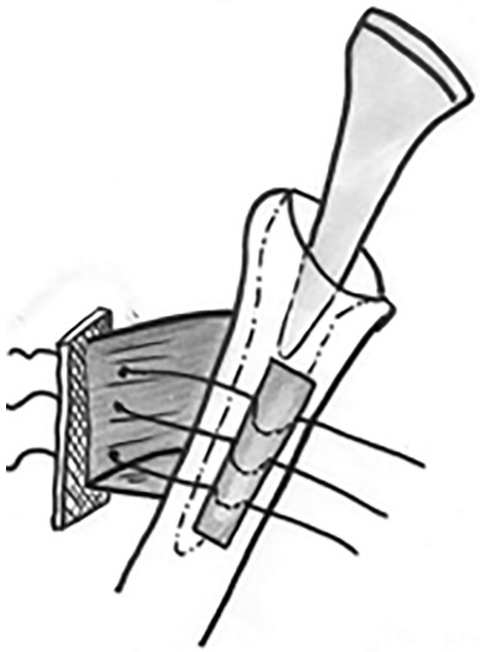


Figure 5. — The sutures are then guided into the osteotomy window around the humeral prosthetic stem.

Figure 6. — The bone block is placed in a flipped manner into the humeral window.

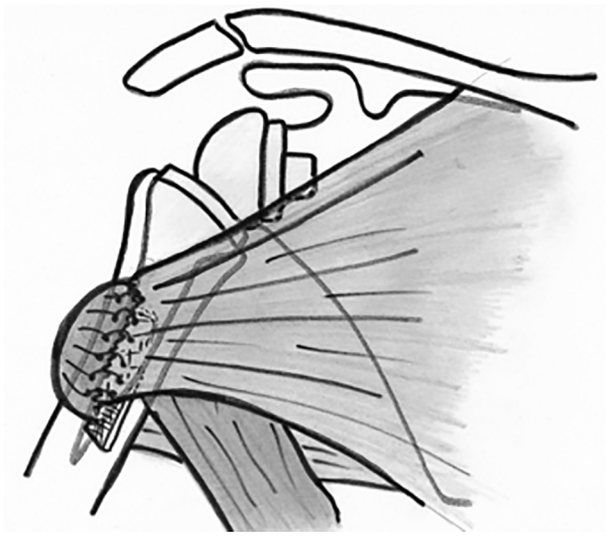


Figure 7. — The pectoralis major is sutured to the musculotendinous transition of the teres.

50% (Figure 6). Next the tendon of the pectoralis major is sutured to the musculotendinous transition of the teres major (Figure 7). Finally the wound is closed in a conventional way after the prosthesis is definitely assembled with the appropriated inlay.

Aftercare

For the LD-BB group, a 6 weeks immobilisation in a shoulder external rotation splint with neutral rotation was used ; passive mobilisation was encouraged the first 6 weeks. After 6 weeks progressive active mobilisation is started and return to daily activities could be started from 12 weeks postoperative.

In the LD+BB procedure a relative immobilisation is prescribed for the first days postoperatively to prevent early postoperative haematoma. If no wound problems (as swelling or leaking wounds) are encountered we consider this construction as solid enough that it gives the possibility to perform early mobilisation without the need for immobilisation. Activities of daily living are encouraged as early as possible. At six weeks strengthening exercises are started after a radiological examination on which the incorporation of the bone graft into the window can be nicely monitored.

Outcome

A clinical and radiographical evaluation of the patients was performed at 3 months, 6 months and 1 year postoperatively by one of the co-authors. The clinical outcome was measured by the Constant Murley Score (CMS) at 3 months, 6 months and one year. The ADLER-score (Activities of Daily Living Requiring External Rotation) and satisfaction rate was evaluated at one year. Radiographic evaluation at 3 months, 6 months and 1 year was used to evaluate the ingrowth of the bone block.

RESULTS

Population

In total 32 patients met the inclusion criteria. In 22 patients a LD+BB was performed. One patient was lost to follow up. 10 patients had the LD-BB procedure. 2 of the patients of LD-BB were lost to follow up. In total 29 patients were evaluated. .

Postoperative functional outcome

In both groups the Constant Score increased significantly at 3 months, 6 months and one year. (Mann Withney U test : LD+BB $p<0,001$, LD-BB $p = 0,002$) (Table 1). There is no significant difference between the two groups (Fisher's Exact Test $p = 0,553$ at 3 months, $p = 0,960$ at 6 months and $p = 1,000$ at 1 year postoperative).

There was no significant difference between the ADLER-score at one year between both groups ($p = 0,582$) (Table 2).

In the LD+BB group we found 46,7% (7 out of 15) of the patients who were very satisfied ; 46,7% of them were satisfied (7 out of 15) and 6,7 % (1 out of 15) disappointed. In the LD-BB group, there were 50% (4 out of 8) of the patients very satisfied ; 50% (4 out of 8) of them were satisfied and no patient was disappointed. All of the patients of the LD-BB group would undergo the same procedure again, while 2 out of the 15 patients would regret the operation in the LD+BB procedure. One patient suffered from an Hornblower's sign in the LD+BB group, while no patient did in the LD-BBgroup. The overall score of satisfaction for the LD+BB

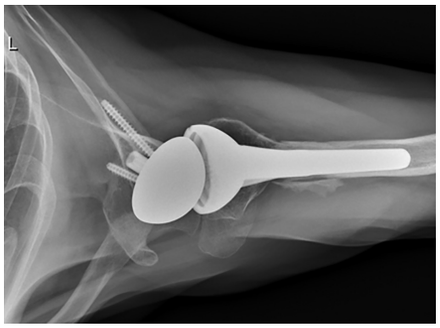
Table 1.

Constant Murley Score		Bone Block				EPISCOPO			
		Preoperative	3 months	6 months	1 year	Preoperative	3 months	6 months	1 year
Pain	/15	7,8	13,5	14,3	14,2	6,4	14,0	12,0	14,0
ADL	/20	11,3	15,5	17,4	19,0	8,4	14,0	15,0	18,0
Mobility	/40	22,6	26,3	31,2	35,4	18,0	25,0	26,0	32,0
Strength	/25	1,0	2,7	3,3	5,2	0,6	1,2	3,0	5,7
TOTAL	/100	42,6	58,0	66,2	73,9	33,0	54,0	57,0	70,0

Table 2.

Activities of Daily Living requiring Active External Rotation (ADLER)		Bone Block	Episcopo
1. Comb hair	/3	2	2,1
2. Shave / Apply make-up	/3	2,6	2,7
3. Dress	/3	2,6	2,9
4. Fill a glass with a full bottle (being sat at the table)	/3	2,4	2,3
5. Drink (bring a full glass to the mouth)	/3	2,6	2,8
6. Eat soup (with a full spoon)	/3	2,4	2,1
7. Eat with a fork	/3	2,6	2,8
8. Shake someone's hand or open a door	/3	2,9	3
9. Use a phone (at ear's level)	/3	2,7	2,9
10. Write a letter	/3	2,8	2,9
TOTAL	**/30**	**26**	**26**
0 = unable to do, 1 = very difficult to do, 2 = somewhat difficult to do, 3 = not difficult at all			

A



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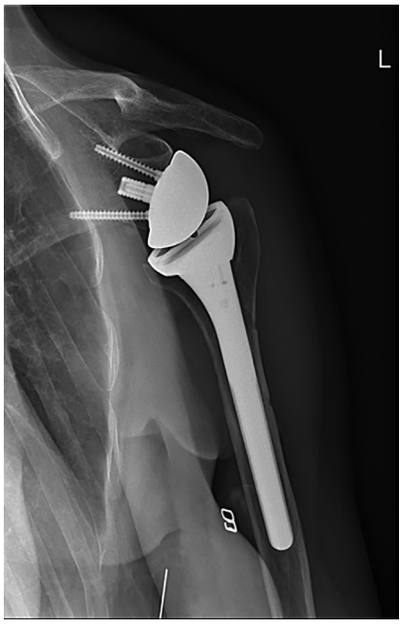

Figure 8. — Radiografic control of ingrowth of the bone block. (A : axial view, B : AP view)

was 8/10 and for the LD-BB group 8,6/10, which is no significant difference (p = 0,779).

The radiological evaluation of the bone block one year after the operation revealed a good position of all of the bone blocks, and a full incorporation and remodellation in all but one patient (1 out of 23 x-rays). That patient sufferd a Hornblower sign and on the X-rays the bone block was resorpted without incorporation. Although this patient scored very satisfied from the operation (Figure 8A-B).

We encountered some complications in the LD+BB procedure group. Two patients had a post-operative haematoma ; one of them needed a surgical evacuation. One of the patients felt and had a periprostetic fracture (Type B), and another patient suffered from recurrent dislocations. A revision was performed in both patients. In the Episcopo we didn't encounter any complications.

DISCUSSION

The rare situation of combined loss of active elevation and external rotation (described by Boileau *(1-3)*) severely affects the ability to perform daily activities in patients with a massive rotator cuff insufficiency. A reversed total shoulder arthroplasty can correct the pseudoparesis of elevation and rebalances the shoulder in the horizontal plane but does not affect the loss in active external rotation

while patients remain disabled because there is no counterbalance of the strong internal rotators *(1)*. The combination with a latissimus dorsi transfer, the pseudoparesis of elevations as well as the pseudoparesis of external rotation can be corrected by rebalancing the vertical plane. Good to excellent clinical outcome has been described in patients with CLEER treated with a reversed total shoulder arthroplasty combined with a latissimus dorsi transfer *(1,2,10-12)*.

We present a technique of combining a reversed total shoulder arthroplasty with a LD transfer with a bony block. Our results show that there is no significant difference in outcome between the bone block procedure and l'Episcopo procedure by measuring the Constant Murley Score and ADLER score. The overall satisfaction of the procedure is similar in both groups. The role of the bone block procedure for a latissimus dorsi transfer in combination with a reversed total shoulder prosthesis may be questionable, but we like to accentuate two advantages : the early mobilisation and radiographic evaluation of the success of the tendon transfer.

While using the bone block procedure, there is no need for immobilisation during the first postoperative weeks due to the solid bone-to-bone interface and the strong circumferential cerclage *(6)*. The patient is able to start mobilisations after a few days, which enhance the rapid functional outcome in daily activities. Tonifications can be started 12 weeks postoperatively. This is in contrast with the recommendation in the article from Boileau et al *(1-3)*and Boughebri et al *(4)*. They describe that there is need for immobilisation in a special brace with 30° abduction and 30° external rotation for 4-6 weeks after the modified l'Episcopo procedure. From weeks 6 to 9 the internal rotation is limited to neutral, and to the greater tuberosity from week 9 to 12. Progressive stretching of the internal rotation and strengthening are started from week 12. The outcome of the procedure should correlate with the postoperative compliance of immobilisation *(1,3)*. Ortmaier et al use a sling for 6 weeks postoperatively, begins at 6 weeks with progressive mobilisations and start with normal daily activities from 12 weeks postoperatively *(11)*. Grey et al uses a immobilisation sling in neutral rotation postoperatively *(10)*. The first 5 weeks external rotation between 0° and 10° is allowed. Internal rotation is increased with 10° every week.

Sequentional radiographic evaluation of the bone block procedure with an X-ray can monitor the position and ingrowth or incorporation of the bone block while starting the mobilisation and tonifications. Evaluation of the tendon transfer and ingrowth is difficult to evaluate in the l'Episcopo procedure. Ortmaier et al uses ultrasonography to evaluate the transfer integrity *(11)*. Magnetic Resonance Imaging is useless because of the metal-artefacts of the reversed total shoulder arthroplasty.

Puskas et al described that the complication rate of the RSA with LD transfer was comparable to an isolated RSA procedure *(12)*. We encountered more complications in the bone block procedure group compared with the modified l'episcopo technique but in our opinion this was not caused by the bone block procedure but are inherent to a reversed total shoulder arthroplasty.

We use a single deltopectoral approach described by Boileau *(1-3)*. In comparison with the double incision technique described by Gerber *(7,8)*, it is easier to perform and there will be less problems of extensive scarring, adhesions and permanent or transient nerve palsies *(4,11)*. By using the single deltopectoral approach the risk of stretching or angulation of the tendon transfer is reduced *(1)*, as well as the risk for neurologic problems as quadrilateral space syndrome by direct vision, identification and protection of the neurovascular bundle.

By harvesting the tendon with a sliver or a block of bone the integrity of the tendons is secured *(11)* and should be less devastating for the muscle activity patterns *(5)* in comparison with detachment of the tendons on the tendon-to-bone interface. Due to the bone-to-bone healing, we have a more secure and solid transfer. Most authors use the LD dorsi and the teres major together to obtain better results : LDtransfer only shows small gains in active external rotation *(3,11)*, moreover the LD tendon is often thin and easily damaged if harvested alone. Using the bone block technique we can transfer both tendons without interrupting or damaging the insertion site.

To fixate the tendon transfer we use circumferential sutures which are proven to be the most solid construction to fixate the tuberosities in a fracture reduction *(6)* and allows the patient for early mobilisation. Boileau initially used tendon-to-tendon sutures by suturing the latissimus dorsi transfer to the stump of the pectoralis major tendon *(2,10)*. To have better biomechanical properties and prevent over tensioning he modified his technique to transosseous sutures fixed to the posterolateral aspect of the greater tuberosity (ie at the insertion of the teres minor) *(1,3)*. Grey et al use suture anchors to determine the optimal length of the tendon and secure it to the distal portion of the greater tuberosity *(10)*.Favre et al determined the posterior side of the greater tuberosity (adjacent to the insertion of the teres minor, opposite the original LD and teres major insertion) as the opimal position of the insertion of the LD transfer *(5)*. It produces a greater exernal rotation moment arm *(3)* and might reduce the limited internal rotation seen by using the stump of the pectoralis major as insertion site of the LD transfer *(3,10,11)*. Boughebri et al *(4)* uses the lateral aspect of the bicipital groove as insertion of the transfer, without having restrictions in internal rotation *(11)*. We reinsert the bone block with the transferred LD and teres major tendons at is original place, but in a flipped manner to have less traction on the tendons and have a greater moment arm for the external rotation. This theoretical advantage cannot be achieved with al bone ship or tendon without bone technique.

In our technique we release the pectoralis major tendon from its insertion at the crista on the humeral shaft to have better view of the insertion sites of the latissimus dorsi and teres major tendons and perform a safe osteotomy of the bone block. Boileau *(1-3)* divide the proximal 2 cm of the pectoralis major to reach the latissimus dorsi and teres major insertion. Ortmaier et al lifted the pectoralis major muscle by inserting a Homann's retractor between the pectoralis major and latissimus dorsi tendon and retract the pectoralis major cranialy and hope to prevent this way pectoralis major weakness and limitations in internal rotation *(11)*.

Limitations of our report are the small patient numbers (bone block procedure : n = 21, Episcopo : n=8).

In conclusion we confirm that the bone block procedure is as effective as the l'Episcopo technique in performing a latissimus dorsi transfer in combination with a reversed total shoulder arthroplasty There is a low rupture rate due to bone block which leads to good tendon integrity, solid ingrowth and allows early mobilisation. Functional results as well as subjective satisfaction and outcome of the patient is comparable to the l'Episcopo technique.

Further studies are necessary to be able to find more advantages or disadvantages of the bone block procedure.

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