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Pedicled pectoralis major transfer for irreparable dehiscence of the deltoid in reverse total shoulder arthroplasty: surgical technique and case report

Marco D. Burkhard, MD [a,*], Florian Grubhofer, MD [a], Karl Wieser, MD [a], Bassem T. Elhassan, MD [b]

[a] Department of Orthopedic Surgery, Balgrist University Hospital, University of Zürich, Zürich, Switzerland
[b] Department of Orthopedic Surgery, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA

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Spontaneous avulsion of the deltoid muscle in cuff tear arthropathy is extremely rare and represents a challenge for reconstruction.[13,24] In such cases, the primary repair of the deltoid in combination with reverse total shoulder arthroplasty (RTSA) may be at risk for failure, as the prosthesis's success is relying on a functionally elongated deltoid.[7,8] Owing to elongation of the deltoid muscle during RTSA, the reconstruction is under high tension and prone to failure. Furthermore, deltoid deficiency after implantation of an RTSA is a severely limiting complication with only a few surgical salvage options. A few studies have reported the pedicled pectoralis major transfer but so far only for patients with deltoid paralysis.[11,20,23] However, the use of this technique for irreparable deltoid dehiscence has so far not been investigated.

We herewith report the combined latissimus dorsi transfer and pedicled pectoralis major transfer on a case with irreparable deltoid deficiency after failure of an RTSA implantation and primary repair attempt of a proximally avulsed deltoid.

Case report

A 64-year-old otherwise healthy man initially presented with a history of right shoulder pain for several years. A full-thickness posterosuperior tear and partial subscapularis tear was detected on magnetic resonance imaging (MRI), with the supraspinatus and infraspinatus retracted to the glenoid (Patte III[25]) and fatty infiltration Goutallier III[12,17] (Fig. 1). Surgical treatment with RTSA was discussed with him. However, besides a weakened abduction and flexion, his shoulder function was unimpaired with symmetrical full range of motion. Therefore, conservative therapy with subacromial steroid infiltration and physiotherapy was initiated. He consecutively did very well after injection and conservative treatment; however, eight months later, he reported a sudden decrease in his shoulder function without a history of trauma. He presented with a pseudoparetic right shoulder with an elevation of 30°, abduction of 20°, and external rotation of 0°. His MRI was repeated and showed avulsion of 6-cm portion of the origin the entire middle deltoid and lateral part of the anterior deltoid from the acromion and lateral clavicle (Fig. 2).

He subsequently underwent RTSA using an anterosuperior approach through the defect of the avulsed deltoid with primary side-to-side and transosseous repair of the deltoid. Multiple sutures using FiberWire (Arthrex, Naples, FL, USA) were used to reattach the deltoid to its acromial and clavicular origin. The shoulder was then immobilized in a 45° abduction brace for six weeks, and active range of motions was started not before three months postoperatively.

However, six months after surgery, he showed persistence of his preoperative pseudoparesis, which was associated with pain requiring daily pain medication. Clinically, it was evident that his deltoid had recurrent dehiscence involving the anterior and middle

Ethical approval was obtained from the cantonal ethics committee of Zürich (BASEC-Nr. 2018–01929), and the patient gave written consent to participate and publish his case-related information and images.

* Corresponding author: Marco D. Burkhard, MD, Department of Orthopaedic Surgery Balgrist University Hospital University of Zürich 8008 Zürich, Switzerland.
E-mail address: Marco.burkhard@balgrist.ch (M.D. Burkhard).

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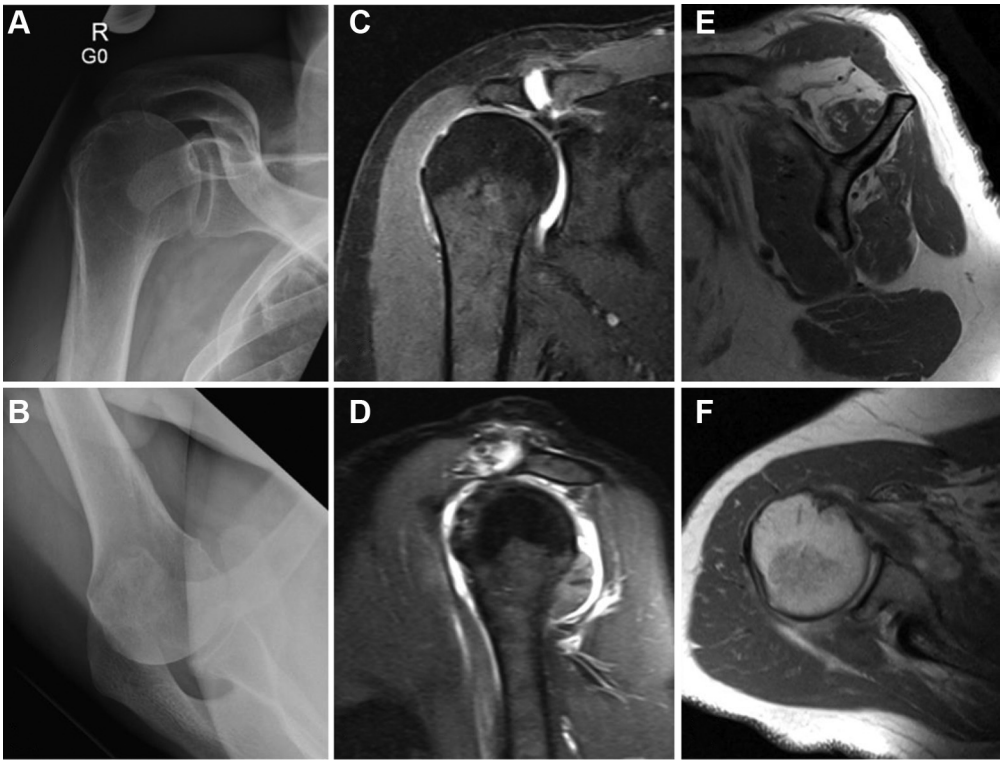

Figure 1 Radiologic imaging on first consultation. (**A** and **B**) anteroposterior- and axillary-view x-rays. (**C**–**F**) MRI showing the massive irreparable rotator cuff tear with posterosuperior retraction to the glenoid and atrophy and fatty infiltration of the supra- and infraspinatus.

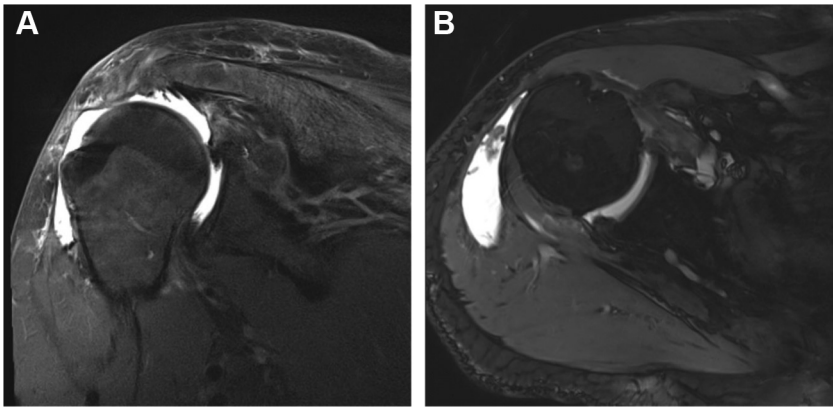

Figure 2 MRI at the second consultation. (**A**) Paracoronal image showing the avulsed deltoid from its origin at the acromion and lateral clavicula with a dehiscence of the detached deltoid of 6 cm. (**B**) Axial image showing the disrupted anterolateral deltoid. The posterior portion of the deltoid remained intact.

part, with an unchanged abduction and elevation of 20° and 30°, respectively, with an additional severe external rotation lag both in neutral and passively abducted arm position. The axillary nerve revealed normal sensation and an intact motor function in the remaining posterior deltoid and anteromedial part. A repeat MRI showed dehiscence and scaring of the deltoid as well as a new teres minor deficiency. Given the precarious situation of a painful and nonfunctioning upper extremity, we recommended reconstructing the deltoid with a pedicled pectoralis major transfer. A combined latissimus dorsi transfer was planned to restore external rotation. He was agreeable to the plan, and a written consent was obtained to publish his case-related information and image.

Surgical technique

The operation was carried out with him in the beach-chair position under general anesthesia and a brachial plexus block with an interscalene catheter. An incision starting at the deltoid insertion extending along the deltopectoral groove and then along the clavicle's inferior border toward the sternoclavicular joint was performed. The dehiscent middle and anterior parts of the deltoid were exposed. In the anterior portion, some muscle tissue remained vital and normally innervated with needle stimulation.

Then, the pectoralis major was exposed. Two separate sutures were placed 6 cm apart on the surface of the middle portion of the

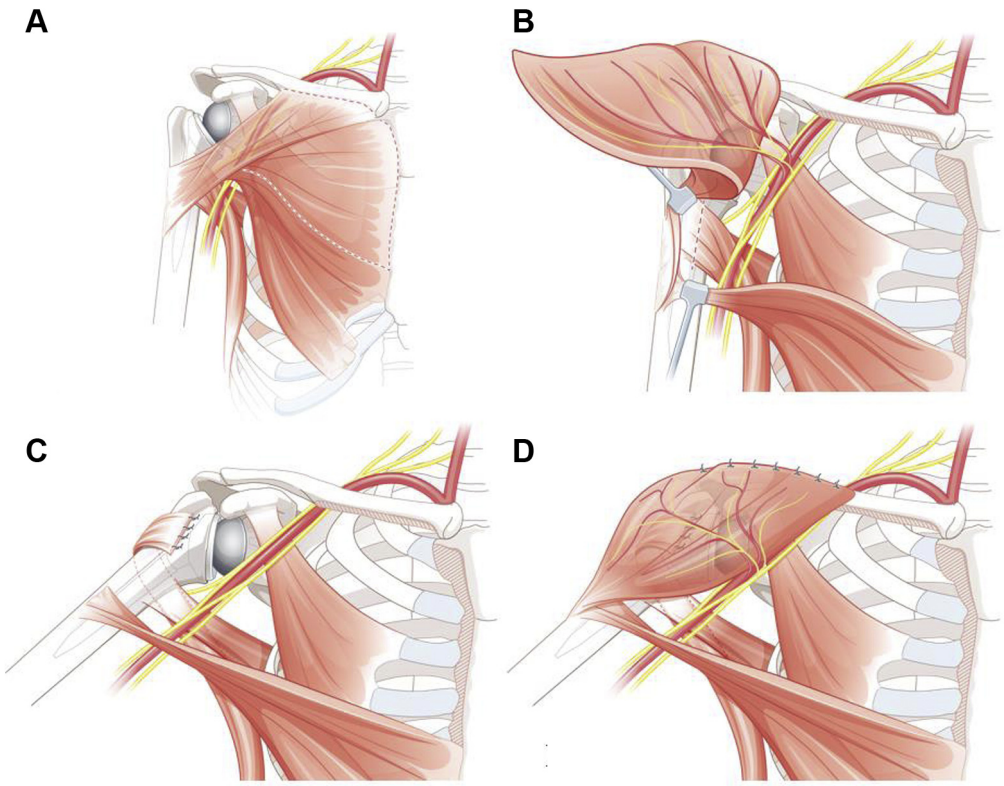

Figure 3 Illustration of the pedicled pectoralis major transfer and latissimus dorsi transfer. (**A**) The pectoralis major muscle can be divided in three parts with origin at the clavicula, the upper sternum and the lower sternum and lower ribs anteriorly. The clavicular and upper sternal portions are exposed and detached from their origin. The lower sternal/abdominal muscle is kept in place. (**B**) The upper two thirds are dissected and the neurovascular pedicle exposed and carefully laterally mobilized. The latissimus dorsi at its attachment is identified through the same approach and detached from its insertion. (**C**) The latissimus dorsi tendon is shuttled around the proximal humerus and reattached at the teres minor insertion site. The pectoralis major muscle is not shown for reasons of simplicity (**D**) The acromion and lateral clavicula is debrided and multiple holes are drilled in preparation of the transfer. The pectoralis major is flipped upside down around the pedicle, so that the deep surface is lying superficially and the upper sternal portion is attached laterally to the acromion and the clavicular portion to the lateral clavicula.

muscle to mark the resting muscle length. The pectoralis major can be divided into three segments: The clavicular head, the upper part of the sternal head, and the lower part of the sternal head. The pedicled pectoralis major transfer encompasses the transfer of the clavicular head and the upper part of the sternal head, while the lower part of the sternal head is left intact (Fig. 3*A*). Fatty tissue lies between the origin of the upper part and the lower part of the sternal head, which can be used as a landmark for this interval. The dissection between the two heads was performed from medial to lateral, and care was practiced to protect the deep neurovascular bundle crossing from proximal to distal. The origins of the clavicular and upper half of the sternal head were detached from the bone with electrocautery. Because the origin of this portion of the pectoralis has enough fascial tissues, peeling of periosteum was not necessary to ensure an adequate, firm transfer. After dissection and elevation of the upper two-thirds of the pectoralis major, special attention was directed to identify and protect the neurovascular pedicle, which lied distal to the middle third of the clavicle. Once the muscle and pedicle were mobilized enough to perform the transfer, it was left in place and covered with a wet pad.

Attention was then directed to expose and harvest the latissimus dorsi tendon through the same approach[4,14] (Fig. 3*B*). As the deltoid and most of the pectoralis major were detached from their origin, the insertion of the latissimus dorsi was easily identifiable at the floor of the intertubercular groove. The latissimus tendon was separated from the underlying teres major and sharply detached and reinforced with a 5-cm-long Krackow suture using two nonabsorbable No. 2 threads (FiberWire; Arthrex, Naples, FL, USA). Additional medial and distal dissection was performed circumferentially around the latissimus to allow maximum possible excursion of the tendon. A large curved instrument was then placed posteriorly around the proximal humerus from medial to lateral, and the latissimus was retrieved posterolaterally (Fig. 3*C*). Next, with the use of an electrical burr, a bony trough was created at the teres minor insertion level. Using 2-mm drills, two transosseous tunnels were created 2 cm apart, aiming anteriorly through the bony bridge, while avoiding the implant. The trough was used to dock the latissimus tendon by passing the proximal and distal latissimus sutures in the transosseous tunnels and tying anteriorly over the bony bridge between the tunnels.

In preparation of the pectoralis major transfer, the lateral clavicle and the anterior part of the acromion were debrided with an electrical burr to expose bleeding fresh bone. Next, six tunnels were drilled into the lateral clavicula and two additional ones in the acromion, using 2-mm drill bits for the transosseous suture fixation. The drills were spaced at least 1 to 2 cm apart to avoid the stress risers and fracture risk. A small Hohmann retractor was placed on the clavicle's undersurface during the drilling to protect the neurovascular bundles located deep to the central aspect of the clavicle. Using a transosseous suture passer (Arthrex, Naples, FL), No. 2 double FiberWire (Arthrex, Naples, FL) sutures were passed through the transosseous tunnels to be used later for the pedicled pectoralis muscle attachment.

Then, the upper two-thirds of the pectoralis were flipped upside down, like a book page, hinging at the pedicle level. In this way, the pectoralis's medial origin was attached more laterally, while the

Table I
Clinical outcome

Variable	Preoperative 1	Preoperative 2	Last follow-up
SSV (%)	20	20	70
Satisfaction	Unsatisfactory	Unsatisfactory	Excellent
Constant score			
Absolute (points)	22	18	57
Relative (%)	24	26	67
Pain (points)	8	8	15
Mobility (points)	10	4	28
Strength (points)	0	0	0

Preoperative 1, before reverse total shoulder arthroplasty (RTSA) and primary repair of the deltoid; *Preoperative 2*, 6 months after RTSA and attempted deltoid repair; *Last Follow-up*, 18 months after pedicled pectoralis majors and latissimus dorsi transfer; *SSV*, subjective shoulder value; *Satisfaction*, Range between unsatisfactory, fair, good and excellent; *Relative Constant Score*, percentage of age- and sex-matched normal scores.

lateral origin was attached medially and the muscle fibers changed from a horizontal direction (adduction vector) to a more vertical direction (flexion vector). Furthermore, the upside-down transfer technique allowed lateralization of the muscle without tensioning the short pedicle (Fig. 3*D*). The potentially most crucial suture was the medial reattachment of the flipped clavicular head, which was placed 2 cm medial to the coracoid base. This suture protected the neurovascular pedicle from tension. The attachment was performed with the shoulder placed in neutral rotation and 60° of flexion. Adequate resting muscle tension and length were ensured by remeasuring the distance between the two marking sutures on the pectoralis surface and confirming the six cm distance between the sutures indicating restoration of the resting muscle length after the transfer. The viability of the muscle was confirmed by inspecting the normal color of the muscle and observing the muscle contraction with needle stimulation. In addition, the pedicle was palpated to make sure it was not under tension. A drain was placed before layered subcuticular incision closure. Postoperatively, the arm was placed in a shoulder spica cast in 60° of flexion. After six weeks, the cast was removed, and passive range of motion in physiotherapy was started. Active range of motion was started eight weeks after surgery. After 12 weeks, light strengthening exercises were initiated and after 16 weeks, he progressed with full strengthening.

Outcome

At the last follow-up at 18 months postoperatively, he significantly improved the subjective shoulder value[15] from 20% to 70%. His absolute and relative (percentage of age- and sex-matched standard scores) Constant score[6] increased from 18% and 26% to 57% and 67%, respectively (Table I). He could elevate his shoulder overhead, perform a minimal external rotation, and internally rotate behind his back (Fig. 4). He had no difficulty reaching on top and behind his head and perform daily activities with small weights/low resistance up to his neck, mouth, and face (ie, eating with cutlery, personal care). However, he was not able to elevate or abduct at 90° against any resistance and overhead activities were only possible with no weights used. In total, he was delighted with his progress and returned to his recreational hobbies, including cycling, and returned to work as an architect.

Discussion

The pedicled pectoralis major muscle transfer has so far only been performed in a few numbers of patients with axillary nerve deficit and corresponding paralysis or paresis of the deltoid muscle.[11,20,23] In this case report, the pedicled pectoralis major transfer was performed as a salvage option for chronic irreparable anterolateral deltoid muscle tear in a patient with an RTSA.

While postoperative deltoid detachments after open and arthroscopic procedures have been frequently described,[5,18,19] spontaneous avulsion of the deltoid in massive rotator cuff is exceptionally rare.[1,3,13,24] The attrition of the deltoid at its origin caused by the superior and lateral migration of the humeral head during resisted abduction has been postulated as its cause.[2,13] In an acute situation, immediate repair of the deltoid is mandated. Sher et al[26] have reported a rate of 67% of unsatisfactory outcomes after direct repair of the deltoid or deltoid-plasty in their cohort of 24 patients with postoperative deltoid disruption. In contrast, Garofalo et al[13] have found satisfactory outcomes in all patients undergoing combined primary deltoid repair and RTSA in a cohort of 18 patients with primarily spontaneous deltoid avulsions. The results of deltoid repair are dependent on tear size and location, with dehiscence of more than 2 cm and involvement of the middle portion of the deltoid being risk factors for failure.[26] In our case, an avulsion of 6-cm distance of the origin of the entire middle portion and lateral part of the anterior portion could be the reason for the failure after attempted primary repair.

A chronic and irreparable injury to the anterolateral deltoid is potentially a severe problem in the setting of RTSA.[8] Several muscle transfers, including pectoralis major, latissimus dorsi, upper trapezius, and more, have been described to enable abduction and flexion.[9,10,22] Of these, the pedicled pectoralis major transfer and pedicled latissimus dorsi transfer have been suggested in combination with RTSA for arthritis and deltoid deficiency.[11,16] The pedicled latissimus dorsi transfer was first published by Itoh et al[21] in 1987 in 10 patients with paralyzed anterolateral deltoid. In this bipolar technique, the latissimus dorsi transfer is detached from its origin and insertion and shifted anteriorly. The pedicle is dissected to the axillary artery, vein, and posterior cord and the muscle rotated around the pedicle to reattach the muscle origin to the acromion and lateral clavicula and distally at the deltoid insertion site. The postoperative flexion ranged between 60° and 150° in these patients.[21] Goel et al[16] has used a pedicled bipolar transfer of the latissimus dorsi in combination with RTSA in a patient with an anterolateral deltoid avulsion and glenohumeral arthritis after a detrimental course after open rotator cuff repair. The patient was able to flex to 135° and externally rotate to 20°.

The concept of the pedicled pectoralis major transfer to substitute an anterior deltoid insufficiency was first described in 1991 by Hou and Tai.[20] They have explored the three distinct functional parts of the pectoralis major with its clavicular origin, sternocostal/upper sternal, and abdominal/lower sternal origin. The muscle is usually supplied by three vessels, the superior thoracic artery to the clavicular origin, the pectoral branch of the thoracoacromial artery to the clavicular and upper sternal origin and the lateral thoracic artery to the lower sternal/abdominal origin. The clavicular and upper sternal portions are innervated by the superior pectoral nerve, whereas the lower part of the pectoralis major is innervated by the middle and lower pectoral nerves. Awareness of the anatomy of these neurovascular bundles is crucial for the success of the transfer. The technique is continuously described as a pedicled transfer with the detachment of the upper two-thirds both from their origin and insertion.[10,11,20,22,23] In contrast, in the case reported here, the insertion of the pectoralis was left untouched, as adequate muscle tension was found after transposing the origin only.

Hou and Tai[20] have reported the pectoralis major transfer for seven patients with a paralyzed deltoid as sequelae of poliomyelitis (5 cases) and brachial plexus injury (2 cases). In three cases, a concomitant trapezius transfer was performed for a paralyzed

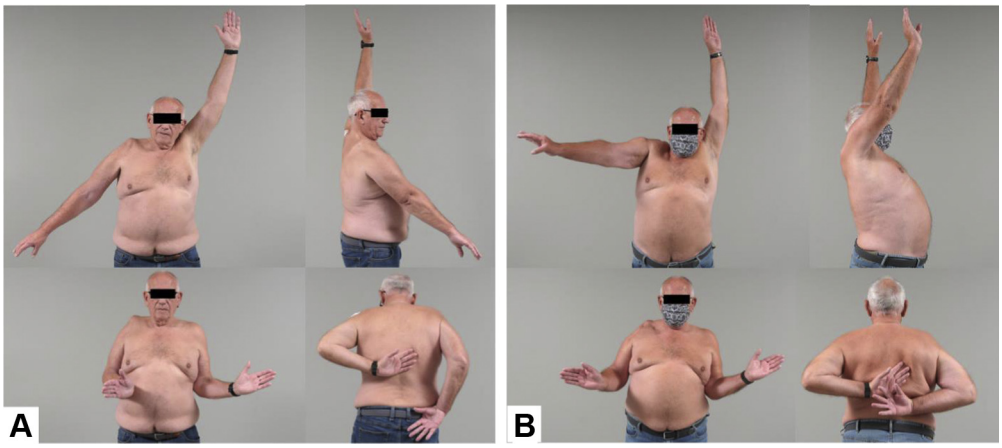

Figure 4 Preoperative and postoperative photo documentation. Range of motion before (**A**) and 18 months after (**B**) the pedicled pectoralis major transfer and latissimus dorsi transfer.

supraspinatus. The abduction improved to 40-90° and flexion to 60-150° 5-20 months postoperatively in their series. Eighteen years later, the same hospital reported eight additional patients with a pedicled pectoralis major transfer for patients with brachial plexus injury.[23] They have reported promising results with a gain of flexion and abduction of 68° and 65°, respectively, after a follow-up of 2-10 years. In 2018, the simultaneous RTSA with pedicled pectoralis major transfer was introduced as a salvage option for 31 patients with end-stage arthritis and deltoid paralysis.[11] The study had shown satisfactory results with an improvement in forward flexion from 15° to 83° and improvements in the disabilities of arm, shoulder and hand score and subjective shoulder value from 54 points and 7% to 33 points and 53%, respectively. The study results are questioning the strict contraindication of implantation of a reverse prosthesis in cases with deltoid deficiency.

The patient in this report demonstrated flexion well above his head, which is far more, than we had expected based on the literature outlined previously. This could be explained by the fact that his posterior deltoid and some part of the anterior deltoid remained vital in him.

Conclusion

This case report demonstrated that reconstruction of a dehisced irreparable large portion of the deltoid origin in the setting of RTSA could be reconstructed with pedicled pectoralis major transfer. The patient outlined in this report demonstrated an excellent outcome with restoration of flexion overhead at the 18-month follow-up.

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