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Effectiveness of vascularized and conventional bone grafting in achieving union in humeral pseudarthrosis

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Introduction Humeral fractures comprise from 5 % to 8 % of all fractures. Nonunion rate of humeral fractures is 5.5–8.7 % with open reduction and internal fixation (ORIF) technique and 3–5.6 % with the use of locked intramedullary nailing technique. Its frequent causes are infection, poor vascularity, severe comminution or technical errors. **Purpose** Analysis of effectiveness of vascularized bone grafting and non-vascularized bone grafting in humeral nonunion and defect treatment. **Material and methods** Surgical management of 69 patients with humeral nonunion was performed from 2010 to 2017 at a single institution in two groups. Vascularized bone grafts were used in 41 cases and non-vascularized ones in 28 cases. X-rays and CT-scans of all the patients were studied. **Results** In the vascularized bone grafting group, union was achieved in 36 cases (88 %) after four to 6 months; in non-vascularized bone group union was achieved in 20 cases (71 %) after eight to 12 months. **Conclusion** In post-traumatic humeral nonunion and bone defects, after two or more failed surgical procedures performed previously, vascularized bone grafting yields more satisfactory results and reduces the total healing time.
Keywords: humeral nonunion, graft, flap, medial condyle, bone defects, vascularized fibular grafts

INTRODUCTION

Fractures of the humerus account for 5 to 8 % of all skeletal fractures [1–3]. Their nonunion rate after plating ranges from 5.5 to 8.7 % of cases, and 3–5.6 % after locked intramedullary osteosynthesis. The problem can present significant difficulties for treatment [4, 5].

Failed outcomes of the operation resulting in pseudarthrosis make re-intervention inevitable [6, 7]. The most frequent tactics of re-operation is removal of the previous implant, re-osteosynthesis, most often with a plate and autoplasty of the humerus with a graft from the iliac crest [2]. The success rate for repeated surgical interventions ranges from 70 to 92 % [3, 8, 9].

Bone grafting with spongy autologous bone is considered a significant factor in achieving bone union in repeated operations and is recommended by most authors who use internal fixation. However, it does not always lead to consolidation [10–12].

If re-operation fails, the surgeon should choose between repeating a previous operation, or changing the surgical strategy. This might be a transition to a different method of fixation and (or) a different way of stimulating regeneration [13–16].

Vascularized bone grafting is one of the ways to manage long-bone defects. The regular graft in this case is a fragment of the fibula. The fibular graft was first described in 1975 [17]. Vascularized bone grafting has been widely used in surgery of the lower extremity; however, recently, many new treatment methods of complex pathologies of the upper extremities with its application have been described [3, 18, 19].

Vascularized bone grafts provide faster healing, have an advantage in infected cases, reduce the risk of subsequent fracture, and have the ability to remodel under physical stress, taking into account early weight loading [4, 5, 18].

An additional advantage of a vascularized bone graft is its possible application if the parthology is osteocutaneous for the reconstruction of the concomitant soft tissue defect and control of blood supply to the graft [20–23].

The aim of the study was to compare the efficacy of vascularized and non-vascularized bone grafting in achieving union in the treatment of humeral pseudoarthrosis and defects.

MATERIAL AND METHODS

The material of the study was the results of treatment of patients with post-traumatic pseudoarthrosis and defects of the humeral diaphysis without active local infection with a history of two or more surgical interventions. In the Department of Microsurgery and Hand Injury of the Federal State Budgetary Institution Priorov NMRC for TO, 41 patients with pseudoarthrosis and defects of the

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humerus (19 males, 22 females) were treated with vascularized bone grafts and 28 patients (13 males, 15 females) with non-vascularized bone grafting in the period from 2010 to 2017 (Fig. 1).

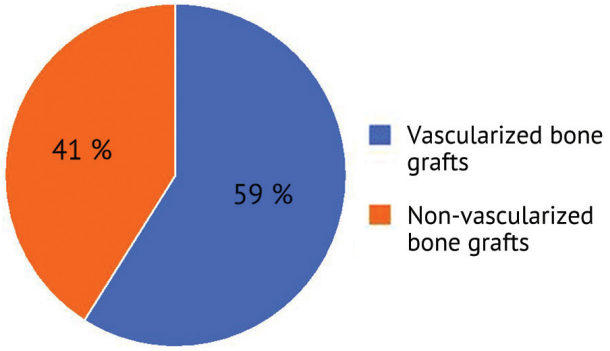

Fig. 1 Distribution of patients according to plasty type

All patients participating in the study gave informed voluntary consent to medical intervention and publication of the study results.

The age of patients in the group with vascularized plasty ranged from 26 to 84 years, the time since the injury to surgery from 17 to 173 months, the number of operations before admission to the NMRC for TO from 2 to 7, using various methods of external and internal osteosynthesis.

The age of patients in the group with non-vascularized plasty was from 18 to 65 years, the time since the injury to surgery was from 13 to 53 months, the number of operations before admission to the NMRC for TO was two or 3 with the use of various methods of external and internal osteosynthesis.

In the study group, vascularized grafts from the fibula were used in 38 patients (93 %), vascularized grafts from the medial condyle of the femur in 3 patients (7 %).

The results were evaluated based on clinical, radiological and statistical methods. The effectiveness of the techniques was assessed by achieving union according to the data of X-rays and CT. The result was assessed as a satisfactory one if a single monolithic adhesion between the graft and humerus fragments had been achieved.

The data were statistically processed. Comparison was made based on the fact of union with the Chi-square test. We also compared the groups in terms of consolidation using the unpaired Student's t-test (for independent samples).

RESULTS

In all cases, bone plating was used for osteosynthesis. In most cases, the plate fixed only fragments of the humerus, bridging the graft. The latter was fixed separately with screws (Fig. 2).

Fig. 2 Fixation by bridging with a fibular graft

If there were indications, surgical revision of the graft in the early postoperative period was performed to restore microcirculation in it.

Fracture consolidation in the vascularized bone grafting group was achieved in 36 cases (88 %) within 4-6 months, including 33 cases with fibular grafts and three cases with the use of a graft from the femoral condyle.

In the group of patients where non-vascularized bone grafting, graft consolidation was achieved in 20 cases (71 %) within 8–12 months.

The dependence of consolidation on the group was revealed. Chi-square = 2.91, p-value = 0.088. The result indicates a statistically significant difference at a significance level of 0.1. The value of p <0.00001, indicates a significant statistical difference in the timing of consolidation in the groups.

Case report

Patient K., 49 years old (Fig. 3), sustained a fracture on January 19, 2008. At the time of admission to CITO, he underwent seven surgical interventions. Diagnosis at admission: pseudarthrosis of the diaphysis of the right humerus.

On 08.12.2010, surgical intervention was performed and included economical resection of the pseudarthrosis of the diaphysis of the right humerus, osteosynthesis with a plate, vascularized bone grafting of the humerus with a fibular graft.

The operation ran under general anesthesia by two teams of surgeons.

One team prepared the recipient area for plasty, performed osteosynthesis of the humerus with a plate and screws. The second team worked with the donor area, the lower leg on the side opposite to the pseudarthrosis.

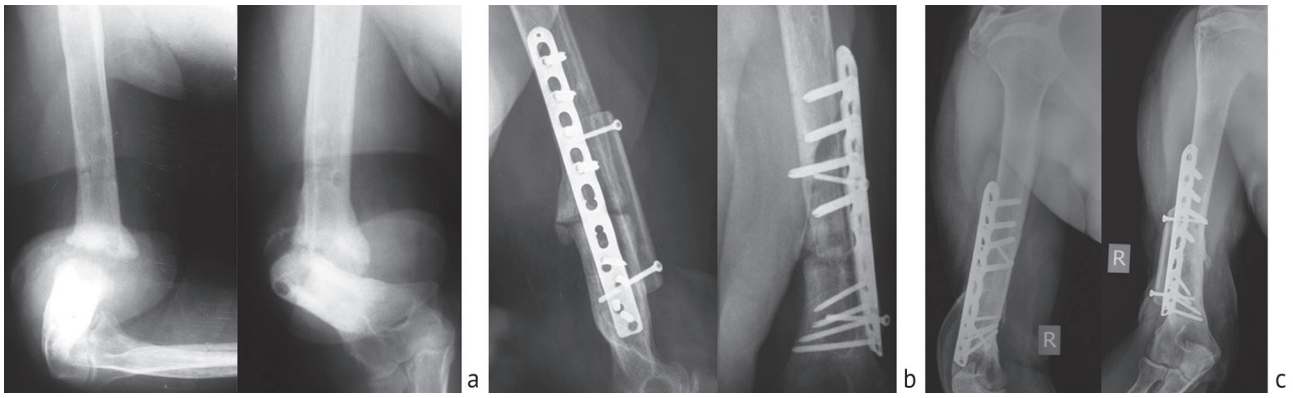

Fig. 3 Patient K., 49 years old: ***a*** radiographs of the right humerus before surgery; ***b*** resection of the pseudarthrosis area of the right humerus, bridging with a vascularized graft from the left fibula; ***c*** radiographs six months after surgery

Graft harvesting

A pneumatic cuff was applied to the lower limb above the knee joint.

On the lateral surface of the lower leg, a skin incision was made in the projection of the fibula. The fibula was then exposed. The anterior tibial neurovascular bundle was preliminarily retracted to the side. The peroneal artery with comitant veins was exposed and mobilized. The distal vascular pedicle was ligated and cut off. Next, the pneumatic cuff was removed. Then, using an oscillator saw, a double osteotomy was performed, retreating distally by 7 cm from the tibiofibular syndesmosis and at less than 5 cm proximally from the head of the fibula. A thorough hemostasis was performed. Next, the proximal vascular pedicle of the graft was cut off (the time of flap ischemia was recorded) and transferred to the team of surgeons working with the humerus.

After treatment of the vascular pedicle (isolation of the artery and veins, ligation of the branches of the vascular pedicle), the fibular graft was fixed side-to-side to the ends of the diaphysis of the humerus distally and proximally monocortically with two screws. Using microsurgical techniques, the graft artery was anastomosed with the brachial artery in the "end-to-side" manner, the graft vein with the basilica vein or the brachial vein in the "end-to-side" manner. After the blood flow had started, inflow and outflow were assessed. A thorough hemostasis was performed. The wounds were sutured in layers, leaving rubber tubes on the humerus and active drainage in the lower leg.

DISCUSSION

The correct choice of the material for bone grafts remains a problem. Plasty with a cancellous autograft from the ilium has long been considered the "gold standard", but new high-tech options for grafting may yield a better or equivalent result causing less trauma to the donor site [24].

In defects of the humerus, the specialist always faces two questions: the choice of the fixation method and the method of defect bridging. In internal osteosynthesis, the choice is between plates and rods [13, 25]. An alternative is external fixation, which can be used both in the fixation mode with additional bone grafting, or in the bifocal mode, using bone transport to fill in the defect [16]. In grafting the defect, the choice is between spongy autologous bone and vascularized grafts [3].

The choice of bone grafting method is determined by the size of the defect. Thus, the use of bone grafts from the iliac crest is indicated for defects less than 5–6 cm long and with well-supplied soft tissues [26, 27]. However, each repeated intervention degrades the quality of the tissues. In addition, the inevitable mobility in the area of the pseudarthrosis leads to instability of the implant relative to at least one of the fragments. This instability is accompanied by bone lysis and, in fact, by formation of a bone defect. In these circumstances, when using standard tactics, large bone resection is required resulting in its shortening [3, 18].

With the development of microsurgical methods, vascularized bone grafting has proven well as the method that can provide a solution to complex reconstructive problems. The use of a free fibular graft for treatment of nonunions of the humeral diaphysis has also gained great popularity in the last few decades [17, 18, 28]. There are two reasons for this. First, increased vascularization at the fracture site is required to accelerate bone healing and resist infection [13]. Second, vascularized bone provides higher biomechanical strength than non-vascularized one [27].

Initially described in the 1970s, vascularized bone grafting has become one of the key techniques for the restoration of long-bone defects. Similar bone anatomy and size make the upper limb one of the most common sites for free fibular grafting [18].

A vascularized fibular graft has advantages in large bone defects, infection, previous history of multiple surgical interventions [5, 18]. The medial femoral condyle graft which has been a relatively recent technique, has been widely used in orthopedic practice for small bone defects, especially in the cases with small defect size and a severely scarred recipient area, where the success of conventional bone grafting is doubtful [20, 29, 30]. Along with the extramedullary blood supply, the medial femoral condyle also posesses a good intraosseous vascularity and contains an average of 30 intraosseous perforating vessels, which are usually concentrated in the inferior distal quadrant of the condyle, which makes it a preferred site for graft collection. Vascularized corticoperiosteal graft from the medial femoral condyle has been shown successful in the treatment of atrophic pseudarthrosis without significant bone defect [12, 18, 31].

The elasticity of the graft allows for its tighter placement around the tubular bone. It is especially convenient when the size of the defect is small, and the use of autologous bone from the iliac wing or fibular graft is problematic [3, 12, 22, 31].

CONCLUSION

Thus, in post-traumatic pseudarthrosis and defects of the humerus after two or more previous surgical interventions, the use of vascularized bone grafting significantly increases the likelihood of consolidation and reduces the term of its achievement in comparison with non-vascularized bone grafting.

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