Current concepts in the treatment of proximal humerus nonunions: a review

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Abstract-Objective: The objective of the current study is to review contemporary concepts regarding the etiology, classifications, and treatment of nonunion following proximal humerus fractures (PHFs). **Materials and Methods**: For the arrangement of this narrative non-systematic review, an exploratory search in the MEDLINE (via PubMed) database using the keywords *"proximal humerus"* and *"nonunion"* for a period covering the last ten years was conducted. The search was performed in November 2024 to include the most recent data available in the literature. **Conclusions:** Proximal humerus nonunion (PHN) is a relatively rare complication following PHFs. The risk of its occurrence is higher in PHFs with medial cortex insufficiency and fractures initially displaced into varus. Poor reduction and lack of fixation stability due to the surgical technique, along with patient-related factors such as smoking, further increase the risk of developing PHN. Researches on the treatment methods involving open reduction and internal fixation (ORIF) for PHN are heterogeneous, with a limited number of studies and a small number of patients, and no method has been established as the gold standard. Regardless of the ORIF method, augmentation with autograft or allograft appears to be mandatory. Compared to ORIF, prosthetic treatment for PHN yields poorer functional outcomes and higher rates of complications and reoperations, regardless of the type of prosthesis.

Keywords: proximal humerus fractures, nonunion, locking plate, intramedullary nail, allograft, autograft;

1. INTRODUCTION

The incidence of nonunion after nonoperative treatment of proximal humerus fractures (PHFs) ranges between 1.1% and 8.2%,[1,2] while for operative treatment, this rate is between 3.3% and 6.4%.[3,4] Most PHFs heal within 6–8 weeks.[5] The definition of nonunion and delayed union is difficult to establish due to the lack of consensus in the

literature regarding specific timeframes for these terms.[2] Although these timeframes vary between 8 weeks and 9 months depending on the authors,[2,6] nonunion is most commonly diagnosed between the third and sixth months after the start of treatment.[2,5,7]

Cadet et al. define nonunion as the absence of progress in bone consolidation between the fragments of the proximal humerus during the period between two radiographs taken 6 to 8 weeks apart.[5]

Although less common, proximal humerus nonunion (PHN) has catastrophic consequences on shoulder function.[8] The causes of PHN are multifactorial, and its treatment ranges from various fixation techniques with or without bone grafting to hemiarthroplasty, anatomical total shoulder arthroplasty, or reverse shoulder arthroplasty.[1–3,5–7]

The objective of the current study is to review contemporary concepts regarding the etiology, classifications, and treatment of nonunion following PHFs.

2. MATERIALS AND METHODS

For the arrangement of this narrative non-systematic review, an exploratory search in the MEDLINE (via PubMed, National Library of Medicine) database using the keywords *"proximal humerus"* and *"nonunion"* for a period covering the last ten years was conducted. The search was performed in November 2024 to include the most recent data available in the literature. Reference lists from the articles retrieved were further examined to identify any additional studies of interest.

Etiology

According to a study by Court-Brown et al.,[1] the incidence of nonunion after PHFs increases from 1.1% to 8% in cases of metaphyseal comminution and up to 10% in fractures with greater displacement between the surgical neck and the humeral shaft (translation between the two fragments of 33%–100%) and fractures displaced into varus with a neck-shaft angle below 90°.[9]

In addition to medial comminution and poor contact between the fragments, complete rupture of the medial hinge in some fractures leads to mechanical instability and disruption of the blood supply between the fragments. The presence of interposed periosteum, muscles, or tendon (most commonly involving the tendon of the long head of the biceps) is also a factor that impairs callus formation.[1,10]

Patient-related factors include poor general health, advanced osteoporosis, comorbidities such as diabetes mellitus, the use of certain medications like corticosteroids, and harmful habits such as alcohol abuse and smoking.[5,6,9] According to a study by Boesmueller et al., the likelihood of developing nonunion after open reduction and internal fixation (ORIF) of PHFs is 3.9 times higher in smokers.[11] Similarly, a study by Klement et al. found that pre-existing inflammatory and degenerative shoulder conditions can double the risk of developing PHN.[12]

Excessive periosteal stripping, poor fracture reduction, and/or lack of mechanical stability after fracture fixation are potential contributors to the development of PHN from a surgical technique standpoint.[5,6,13]

Classification

The most commonly used classification of nonunion of the proximal humerus is by Checchia et al.[14] The classification is based on the anatomical location of the nonunion and the size of the bone defect, and includes four types: Type I**:** results from two-part surgical neck fractures, where due to nonunion, the proximal fragment is small and resembles a fracture through the anatomical neck. This also includes three-part fractures with displacement of the greater tuberosity (GT) < 5 mm. Type II: the nonunion is at the same level, but the proximal fragment is larger. This also includes three-part fractures with displacement of the GT > 5 mm. Type III: occurs in three- and four-part fractures or split fractures of the humeral head, with nonunion at the level of the surgical neck. Displacement of the tubercles (whether healed or not) is > 5 mm. Type IV: Occurs after open fractures and/or post-traumatic osteomyelitis

Another, less commonly used classification is that of Boileau et al., which combines nonunions and malunions.[15] Calori et al. propose a comprehensive but difficult to use classification (Non-Union Scoring System) based on a 100-point scale, evaluating factors related to bone biology, fracture type, and patient-related factors. PHN of is divided into four types based on the total score.[7,16]

Nonoperative Treatment

It is only applicable in patients with high surgical risk and those who cannot participate in the rehabilitation process. In these cases, adequate pain management and modification of physical activities are the only treatment options.[2,5,13]

Basic Principles of Surgical Treatment of PHN

The most problematic nonunions of the proximal humerus are those at the surgical neck, followed by those of the humeral head. Literature data on isolated nonunion of the GT and lesser tuberosity (LT) are scarce, but in most cases, although delayed, the tubercles eventually undergo bone healing. The larger issue with these cases is malunion.[2,6]

Regardless of the surgical treatment undertaken, an existing infection must always be ruled out as a cause of nonunion.[5]

Adequate bone substrate in the humeral head, properly healed tubercles, absence of degenerative changes and collapse of the humeral head, along with the absence of infection, are prerequisites for reconstructive surgery with ORIF.[5]

The surgical principles for any bone with nonunion are as follows: debridement of the fibrous callus and pseudocapsule, removal of avital bone fragments, debridement of the bone edges until viable (bleeding) bone is present, and removal of fibrosis from the medullary canal. The presence of stiffness requires arthrolysis and removal of adhesions in the subacromial space, which is important not only to support the subsequent

rehabilitation process but also to reduce stress forces at the site of nonunion.[3,5,6] There is often significant loss of bone substrate in the metaphyseal region of the humerus. This necessitates shortening the bone to achieve good bone contact with vital bone ends, which is generally well tolerated by patients.[3,5,6]

The type of nonunion must also be considered. Atrophic nonunions are most often due to inadequate vascularization with compromised bone biology. On the other hand, in hypertrophic nonunions, the bone has adequate blood supply but lacks sufficient mechanical stability. Oligotrophic nonunions may result from a combination of these factors.[17] Augmentation with autograft or allograft is suitable for all types of nonunion, as it not only serves a biological function but also contributes to achieving mechanical stability and filling bone defects resulting from bone loss and/or osteopenia of the humeral head.[8,13]

Significant bone loss of the humeral head, collapse of the humeral head, degenerative changes in the glenohumeral joint (GHJ), and the presence of malunited tubercles with PHN are indications for choosing shoulder arthroplasty over reconstruction with ORIF.[18]

ORIF with Locking Plate

Although good results have been reported with the use of non-locking T-plates and blade plates, the biomechanical advantages of the locking plate (LP) have made it the preferred implant for treating PHN in the last decade.[3,13,19] Augmentation with non-resorbable sutures through the tubercles (even if they are united) and their fixation to the LP contributes to stability and should be applied in cases of PHN.[3,2]

Regardless of the implant used, the number of authors relying solely on plate fixation without graft augmentation is very small. Quadlbauer et al. used fixation with a LP without grafting in 9 patients with atrophic PHN, with an average age of 72 years, achieving 100% union with good to excellent clinical results and no complications.[2]

ORIF with Locking Plate and Autograft

In a systematic review by Zastrow et al., the use of ORIF with LP in nonunion of PHFs resulted in a 97% union rate. In 76% of ORIF cases, augmentation with a graft was applied, with 46.5% using an autograft from the iliac crest and the remaining cases using allograft. The use of autograft resulted in a significantly shorter time to bone union compared to allograft (3.9 vs. 5.5 months).[3]

Gao et al. used a non-vascularized fibular autograft in 7 patients with atrophic PHN, with an average age of 58.4 years. Five of these patients were initially treated surgically. The authors reported complete union in all patients, with the Constant-Murley score (CMS) increasing from 25.7 preoperatively to 77.7 postoperatively. One patient was diagnosed with superficial peroneal nerve palsy, which fully recovered within 4 months.[21] Similar results were reported by Mukhopadhaya et al. in 6 patients with an average age of 54.3 years.[22]

Carlock et al. treated 16 patients with PHN at an average age of 59.7 years. Twelve patients had atrophic nonunion, three had hypertrophic nonunion, and one had oligotrophic nonunion. In 14 patients, the authors used a LP and an autograft from the iliac

crest to fill the defect in the humeral head, adding bone morphogenetic protein (BMP) in 4 cases. In two patients, they used aspirated bone from the iliac crest combined with a cancellous allograft. In 6 of the 16 patients, fibular allografts were used due to varus deformity or lack of medial cortex contact. Union was achieved in all patients, with a mean time to union of 5.4 months postoperatively. No complications were reported at the donor site, although one patient developed avascular necrosis of the humeral head.[23]

Matsumae et al. used a vascularized autograft from the scapula of the same limb in one case involving a patient with atrophic nonunion. They reported favorable functional outcomes and successful bone union after 3.5 months postoperatively.[24]

Despite good outcomes with autografting, the possibility of donor site morbidity should be considered. The complication rate for non-vascularized fibula autografts has not been fully clarified, but with the use of iliac crest autografts, the complication rate reaches 20.6%.[25]

ORIF with Locking Plate and Allograft

Although allografts have lower osteoinductive and lack osteogenic properties compared to autografts, they avoid complications related to the donor site. Their main disadvantage is the increased risk of transmitting viral and bacterial infections. However, with gamma sterilization of allografts and strict screening programs, including mandatory testing of donor blood samples, this risk is minimized.[25,26]

Badman[8] introduced the use of fibular allografts in PHN (**Fig. 1**). In his pilot study, the author achieved bone union in 17 out of 18 patients with an average age of 60.4 years. Seventeen patients had oligotrophic nonunion, and one had hypertrophic nonunion. Radiographic union occurred with an average time of 5.4 months postoperatively. The functional outcome, as measured by the ASES score, improved by 41 points (from 40 to 81). Two patients had transient radial nerve palsy, and three patients developed adhesive capsulitis, which required further release.[8]

Rollo et al. used an allograft from the humeral diaphysis in 16 patients with atrophic PHN, with an average age of 62.3 years. Twelve patients were treated with a LP, while in four patients an intramedullary nail was used for fixation. Union was observed in all patients with an average time of 3 months postoperatively. The CMS increased from an average preoperative of 26.4 to 76.3 postoperatively. No complications were reported.[27]

Figure 1. A 62-year-old patient with PHF. Top row: left – diagnostic radiographs; right – radiographs at eight months post-trauma, showing nonunion and secondary dislocation of the fracture. Bottom row: left – postoperative radiographs. ORIF, anatomical reduction, fixation with a locking plate, and augmentation with an intramedullary allograft from fresh frozen fibula; right – radiographs at 2 years postoperative, showing bone union with active shoulder abduction. Clinical case: Second Clinic of Orthopaedics and Traumatology, University Multiprofile Hospital for Active Treatment and Emergency Medicine "N. I. Pirogov", Sofia, Bulgaria

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ORIF with Intramedullary Nail and Autograft

Initial studies on the treatment of PHN with intramedullary osteosynthesis and autograft show promising results.[28,29] In a recent study, Inci et al. used compressive intramedullary nail in 15 patients with nonunion, with a mean age of 47.3 years. Twelve of the patients had atrophic and three had hypertrophic nonunion. In twelve cases, autografts from the iliac crest and cancellous bone from reaming the humeral canal were used, while three patients received only cancellous bone. Union occurred in 14 of 15 patients within a mean of 16.6 weeks. The functional outcomes, based on the CMS, were excellent in 9 cases, good in 4, and poor in 1. Transient ulnar and radial nerves palsy were the only complications observed in two patients.[30]

Hemiarthroplasty and Anatomic Total Arthroplasty for Proximal Humerus Nonunion

Hemiarthroplasty is suitable for cases of PHN where the rotator cuff function is preserved and no degenerative changes are present in the GHJ. However, when arthritis

is present in the joint, an anatomical total arthroplasty is recommended.[5,6] Research on these techniques in the last decade is limited, and its use has become less common due to unsatisfactory functional results and a high complication rate. A systematic review from 2020 by Zastrow et al. of 137 patients with a mean age of 63.9 years reported an 18.2% complication rate, 10.8% reoperations, and a mean CMS of 66.8. Prosthetic dislocation was the most common complication at 5.8%.[3] A recent study by Marigi et al., involving 21 patients treated with hemiarthroplasty for PHN, confirmed these results.[31]

Reverse Shoulder Arthroplasty for Proximal Humerus Nonunion

For nonunion cases with traumatic or degenerative damage to the rotator cuff, reverse shoulder arthroplasty (RSA) is the preferred treatment.[5,6] While RSA is increasingly used for degenerative conditions of the GHJ and PHFs due to better functional outcomes,[32] it does not yield superior results in nonunion cases compared to hemiarthroplasty or anatomical bipolar arthroplasty.[3] A systematic review by Zastrow et al., based on 125 patients with a mean age of 70.7 years, found complication rates of 21.6%, reoperations at 14.4%, and a mean CMS of 59.4. Prosthetic dislocation was the most common complication, occurring in 16% of patients. The risk of dislocation was five times higher in patients who underwent tuberosity osteotomy. According to Cheung et al., changes in the anatomy of the proximal humerus or nonunion of the tuberosities compromise the deltoid muscle tension, increasing the risk of prosthetic dislocation.[33]

A 2024 study by Tagliero et al. showed similar results. In 50 patients with PHN, the use of reverse prosthesis led to a 36% complication rate and 20% reoperation rate. The authors identified younger age and diabetes mellitus as factors significantly increasing the risk of complications and reoperations.[34]

3. CONCLUSIONS

PHN is a relatively rare complication following PHFs. The risk of its occurrence is higher in PHFs with medial cortex insufficiency and fractures initially displaced into varus. Poor reduction and lack of fixation stability due to the surgical technique, along with patient-related factors such as smoking, further increase the risk of developing PHN. Researches on the treatment methods involving ORIF for PHN are heterogeneous, with a limited number of studies and a small number of patients, and no method has been established as the gold standard. Regardless of the ORIF method, augmentation with autograft or allograft appears to be mandatory. Compared to ORIF, prosthetic treatment for PHN yields poorer functional outcomes and higher rates of complications and reoperations, regardless of the type of prosthesis.

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