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Research Progress in Surgical Treatment of Proximal Humeral Fractures in Elderly Osteoporotic Humerus

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Abstract: *Proximal humeral fracture is a common injury in middle-aged and elderly people, especially elderly patients with osteoporosis due to bone loss, which can lead to fractures due to low-energy injury. As the population ages, the prevalence of proximal humeral fractures is likely to continue to increase. In the absence of open or neurovascular injury, the indications for surgery for proximal humeral fractures are controversial. Typically, the same fracture type can be treated non-surgically, with open reduction internal fixation, or joint replacement, depending on several variables including patient age, comorbidities, activity level, and treatment expectations. The purpose of this paper is to review surgical considerations in the surgical treatment of proximal humeral fractures in older adults with osteoporosis.*

Keywords: *Proximal humeral fracture, Treatment, Humeral head replacement, Reverse total shoulder arthroplasty*

1. Introduction

Proximal humeral fractures are more common in adults, accounting for about 5% of all fractures, and the proportion is increasing in the elderly population [1]. Most proximal humeral fractures do not require surgery, and conservative treatment can be very effective. The decision to perform surgery depends on the patient's comorbidities, functional needs, bone quality, and surgeon experience. The classification of proximal humeral fractures, the characteristics of individual patients, the expertise of surgeons, and the availability of conservative treatment make surgical decisions complex and difficult [2]. Low-energy proximal humerus fractures, such as those that occur from a fall from standing height, are often associated with osteoporosis. In one study, osteoporotic bones significantly increased the risk of proximal humeral fractures. The risk of osteoporotic bone fractures is 2.6-fold increased compared to non-osteoporotic bone [3]. Poor bone quality can lead to comminuted fractures, thinning of cortical bone, and fragmentation of cancellous bone, which makes it challenging to obtain and maintain reduction and achieve adequate plate fixation [4]. The locking steel plate provides internal fixation of the fixing angle and the risk of screw retraction is low. However, there are still challenges in treating patients with poor bone quality, such as varus collapse and screw shedding [5]. A better understanding of the factors influencing internal fixation failure and better early outcomes of shoulder replacement have led to increased use of shoulder replacement in the treatment of proximal humeral fractures.

2. Fracture classification

Neer classification of proximal humeral fractures is based on 4 major fracture sites, including large tubercles, small tubercles, humeral head, and humeral shaft [6]. The classification and its subtypes are fully described in an article by Carofino and Leopold [7]. Fractures are discussed in terms of the number of Neer parts involved. If the fragment separates by more than 1 cm or the angle exceeds 45°, the fragment is considered displaced. Group I includes all fracture types that have not been displaced, also known as partial fracture. Group II includes humeral anatomical neck fractures with displacement or angle, which is called two-part fracture. Group III was humeral surgical neck fracture with other displacement or angle, including three subtypes. The first subtype is a single diaphysis displacement,

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which is a two-part fracture. If a nodule fracture is combined at the same time and the displacement is greater than 1 cm, it should be a three-part fracture. If fractures of two nodules are combined at the same time, and both have a shift greater than 1 cm, the upper end of the humerus is divided into four separate bone pieces, which is a four-part fracture. Group IV consisted of two- or three-part fracture, with large nodules fractured and displacement greater than 1 cm. Group V includes small nodule fractures, which may have small nodules displaced or angled to form two-part fracture, and may also have humeral surgical neck fractures to form three-part fracture. Group VI included fractures of the upper humerus combined with true complete dislocation of the glenohumeral joint, which were divided into anterior and posterior glenohumeral dislocations and partial dislocations of the humeral head with facet fractures [7].

In 1934, Codman et al. introduced a classification system based on the location of proximal humeral fractures. He classified the proximal humerus into four regions, namely the humeral diaphysis, the humeral head, the large tubercle of the humerus, and the small tubercle of the humerus. There are 12 fracture classification types [8]. However, the Codman classification system does not distinguish between anatomical neck fractures of the humerus and the surgical neck, and does not provide a good description of the displacement of fracture pieces of the proximal humerus. Hertel et al. [9] improved the Codman classification system and identified risk factors for avascular necrosis of the humeral head by describing the morphology of fractures. They found that shortening of the medial metaphysis of more than 8 mm after the humeral head fracture block, rupture of the rotational axis of the medial cortex, and displacement of more than 2 mm were predictors of avascular necrosis of the humeral head.

3. Imaging evaluation

Plain X-rays are one of the main means of diagnosis, classification, and treatment of proximal humeral fractures. The proximal humerus should be imaged in at least two planes. Routine evaluation includes anteroposterior shoulder position at the level of the scapula, lateral shoulder blade position, and lateral axillary position where the patient lies on the back [10]. Measuring bone mineral density (BMD) using standard X-rays of the shoulder is a useful preoperative technique. Tingart et al. [11] describe a technique to judge proximal humerus BMD using cortical thickness of the medial and lateral cortex in the orthostatic view. The researchers determined that a combined cortical thickness of less than 4 mm was associated with significantly reduced BMD compared to humerus thicker than 4 mm. Color doppler ultrasound can be used to evaluate for associated vascular injury and accompanying rotator cuff tears [12]. Computed tomography (CT) is used to assess complex fracture patterns, while it also allows quantification of available bone mass and assessment of the extent and location of fracture healing. Krappinger et al. [13] describe for the first time a technique to measure proximal humerus BMD using a helical CT scan. Measurements of proximal humerus BMD measured on CT correlate with measurements in different parts of the body, including the lumbar spine, proximal femur, and forearm. A recent study compared the Krappinger technique to several other techniques using quantitative CT and high-resolution CT. The bone mineral content of the joint region measured using clinical quantitative CT showed the highest correlation with circulatory load versus failure in the control group [14]. This could be a useful new technique with greater accuracy than traditional methods of measuring BMD. CT angiography can accurately diagnose and guide the interventional treatment of arterial injury [15]. Magnetic resonance arthrogram and angiography are additional high-quality imaging tools used to assess periarticular soft tissue and vascular damage, respectively [16].

4. Conservative treatment

Non-surgical treatments include analgesia and sling fixation. In general, conservative management is best for patients with non-displaced fractures of the proximal humerus or who are medically unsuitable for surgery [17]. Studies have found that early physical therapy started two weeks after injury is more effective than prolonged immobilization. The shoulder should be placed in a sling and early physiotherapy performed. Isometric, pendulum, or passive range-of-motion exercises should begin two weeks after injury. The sling can be worn until the fracture heals, which usually occurs in 4 to 6 weeks. Around this time, active strength training can begin [18]. A recent study by Clement et al. [19] included 211 cases of proximal humeral fractures in patients aged 65 to 98 years. After 1 year of follow-up, Constant-Murley scored an average of 68.8 points. Three- and four-part fracture are treated nonoperatively but are not effective. Complications of conservative management at this time include malunion, bone nonunion, subacromial impingement, and avascular necrosis of the humeral head [20].

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Malformation of the proximal humerus severely limits external rotation and abduction because the large tubercle is not in the correct anatomical position. Regarding osteoporotic fractures in older patients, most patients are still undergoing non-surgical treatment because they are older at presentation, have low functional requirements, and have severe comorbidities [21].

5. Internal fixation therapy

Adults with sufficient bone mass can benefit more with open reduction and internal fixation. This technique can yield positive results, especially in fracture types with large and strong nodular fracture fragments. After the introduction of locking steel plates, the indications for such treatment increased [22]. Traditionally, at the metaphysis with poor proximal humerus, screw fixation carries the risk of screw detachment. Biomechanical studies have shown that the decrease in BMD has a large effect on the grip strength of the screw. The advent of locking steel plates made it possible to maintain the screw structure in a fixed angular position regardless of bone mass, and the clinical results of locking steel plates fixation in the treatment of fractures of the proximal humerus proved successful [23]. Meta-analysis of locking steel plates for proximal humeral fractures showed a mean overall score of 74 points, a mean follow-up of 18 months, 2 partial fractures 79 points, 3 part fractures 72 points, and 4 partial fractures 66 points [24]. Despite improvements in steel plate technology, complications and revision rates remain a concern. A study evaluating the outcome of complex proximal humeral fractures in older adults showed a 51% early failure rate and a 26% revision rate during incisional reduction internal fixation for the treatment of 82 proximal humerus fractures. The authors concluded that open reduction internal fixation of these fractures using locking steel plates had unavoidable displacement of fracture fragments, thereby preventing patients from achieving acceptable results [25]. The causes of complications are multifactorial and involve patient-related factors (e.g., comorbidities, smoking), fracture-specific factors (e.g., bone mass, comminutedness, fracture type), surgical factors (e.g., plate/screw placement, reduction quality), and postoperative rehabilitation. In the meta-analysis by Sproul et al. [24], varus malformation healing was the most common complication (16.3%), followed by avascular necrosis (10.8%), screw detachment (7.5%), subacromial impingement (4.8%), and infection (3.5%). Screw breakage is the most common cause of revision surgery. Several other studies have also reported screw breaking as a common complication, occurring between 7% and 57%. In some patients with a high incidence of three- and four-part fracture, more than 50% require revision surgery for joint replacement, and articular erosion due to screw penetration severely limits revision options and adversely affects long-term outcomes [25].

6. Humeral head replacement

Neer was the first to introduce humeral head replacement (HHR) as an alternative treatment. HHR provides a good solution for proximal three- and four-part fracture of the humerus and provides pain relief. The key to the success of a HHR is that the nodule remains intact, which provides satisfactory results and good range of motion [26]. Many researchers have emphasized the importance of anatomical nodule reattachment and proper prosthetic positioning in restoring rotator cuff function and optimizing outcomes after HHR. Improvements in modular implant design enable the height and offset of the prosthesis to be finely adjusted after implantation and correlated with meticulous surgical techniques and rehabilitation for better outcomes. Long-term follow-up of fracture types treated with HHR confirmed pain relief in patients, but functional outcomes varied. Better outcomes can be achieved in younger patients and those with fewer comminuted nodules, and incorrect backward tilt, poor nodule positioning, and too high prosthesis height are thought to be factors associated with adverse functional outcomes. Thus, HHR provides significant pain relief, but range of motion and outcome are variable, often depending on tuberous misalignment and bone discontinuity [27]. When using HHR, correct implant placement and nodule reduction and fixation are critical. Complications of HHR include aseptic loosening, dislocation, infection, reflex sympathetic dystrophy, subacromial impingement, intraoperative or periprosthetic fractures, and ectopic ossification [28]. Poor outcomes were associated with advanced patient age, head and joint mismatch due to prosthesis misalignment, increased nodule displacement, persistent neurological deficit, and the use of HHR to save previously failed conservative treatment or surgical reconstruction. HHR has shown satisfactory pain relief at long-term follow-up, but overall functional outcomes remain difficult to predict [29].

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7. Reverse total shoulder arthroplasty

Paul Grammont originally proposed a technique called reverse total shoulder arthroplasty (RTSA) for the treatment of glenohumeral arthritis [30]. However, it is now used for many indications such as rotator cuff injuries and proximal humerus fractures, among others. In addition, this technique has been applied to complications of proximal humeral fractures, such as deformity healing or bone disunion, chronic dislocation, and revision arthroplasty, and has become a pioneer treatment option for complex shoulder injuries and diseases in older adults [31]. Unlike HHR, RTSA does not require the nodule to be intact to achieve a successful outcome. RTSA works through 3 specific mechanisms: 1) centering the glenohumeral rotation center; 2) distalize the center of rotation, thereby tightening the deltoid muscle; 3) Achieve a more constrained joint, which allows the shear force of shoulder abduction to be converted into a compressive force [32]. The indications for RTSA for proximal humeral fractures are older adults with non-reconstructable fracture types, and for high-risk fracture patients with poor functional potential outcomes after treatment with incision reduction internal fixation or HHR [33]. Contraindications include axillary nerve dysfunction, deltoid muscle dysfunction, scapular or acromion fractures, and open fractures due to high risk of infection. Complications associated with RTSA include intraoperative fractures, nerve damage, prosthetic misalignment, and loosening [34].

8. Conclusion

Treatment of proximal humeral fractures in older patients with osteoporosis remains a challenge in terms of when and how to operate. A good prognostic outcome depends on a detailed fracture evaluation, careful patient selection, full consideration of individual patient characteristics, complications, and functional expectations, and advanced surgical expertise in a wide range of reconstruction and joint replacement protocols. Currently, available evidence suggests that treatment should be individualized and tailored to specific fractures, patients, and other relevant factors.

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