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Research Progress of Surgical Treatment of Subtrochanteric Fracture of the Femur

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Abstract: Subtrochanteric fracture refers to the fracture between the lesser trochanteric of the femur and the isthmus of the femoral shaft. It usually refers to the fracture within 5cm below the lesser trochanteric of the femur, accounting for about 25% of hip fractures. This type of fracture is usually treated with surgery. Without surgical reduction and fixation, patients are at high risk of malunion or non-union. At present, there are two main surgical options for subtrochanteric fractures of the femur: extramedullary fixation and intramedullary fixation, intramedullary fixation is considered to be the "gold standard". However, the treatment of subtrochanteric fractures is still a great challenge for orthopedic surgeons due to the special anatomical structure of the subtrochanteric region of the femur, especially due to the difficulty of reduction at the fracture site. The purpose of this review is to introduce the current surgical protocols for subtrochanteric fractures and their advantages and disadvantages, to provide some references for clinicians in the treatment of subtrochanteric fractures.

1. Introduction

The subtrochanteric area is the transition area from cancellous to cortical bone and the area where blood supply is unfavorable. The age distribution of patients with subtrochanteric fractures was bimodal. In middle-aged and young adults (mostly males), comminuted fractures of the proximal femur were mainly caused by high-energy trauma, such as high-speed trauma, which was characterized by obvious displacement of fracture end, soft tissue injury, and interruption of blood supply at the fracture site. Elderly patients (mostly female) were mainly due to low-energy trauma, such as simple falls, and were often accompanied by osteoporosis, resulting in spiral fractures of the proximal femur. The subtrochanteric region is an anatomic region with unique mechanical and biological characteristics. Stress concentration is the highest in the whole body. Multiple deformable forces are applied to the proximal and distal fragments of the fracture, forming characteristic deformities: At the proximal end of the fracture, the gluteus medius and gluteus minimus cause abduction, the iliopsoas cause flexion, and the external rotation muscles cause external rotation; At the distal end of the fracture, the abdominalis and adductor muscles cause adduction and shortening. The action of these forces leads to the typical varus deformity and makes the intraoperative reduction of the fracture more difficult. Nonsurgical treatment of subtrochanteric fractures often results in shortening and rotational malformations or nonunion of the fracture, hiding

recovery of function in the affected limb. Nonsurgical treatment also requires prolonged immobilization and bed rest of the affected limb, increasing the incidence of attacks, pneumonia, thromboembolic events, and bedsores, and increasing the risk of death. Therefore, non-surgical treatment of subtrochanteric fractures of the femur is often not a viable option. Of course, a small number of patients whose medical conditions do not tolerate surgery or who are receiving hospice care may be considered for non-surgical treatment[1]. The surgical treatment of subtrochanteric fractures can be divided into two surgical methods: extramedullary fixation and intramedullary fixation. Devices used for extramedullary fixation include compression locking plates at the proximal femur, 95 ° Angle plates, minimally invasive fixation systems, dynamic hip screws, etc. Intramedullary fixation is relatively more consistent with the line of force, facilitates load transfer, and is more biomechanical. In addition, intramedullary fixation is superior to extramedullary fixation in shortening hospital stays, reducing intraoperative blood loss, shortening operative time, starting time of postoperative weight bearing, and functional recovery of the affected limb[2]. Therefore, intramedullary fixation is currently considered the "gold standard" in the treatment of subtrochanteric fractures. At present, the commonly used devices for intramedullary fixation include PFNA, Intertan, etc.

2. Treatment options for extramedullary fixation

2.1. Proximal femoral Compression locking Plate (PF-LCP)

The PF-LCP improves on the previous proximal femoral plate, making the anatomical structure more suitable for the proximal femur, and the screw head is locked to the plate, resulting in a stable structure. At the same time, PF-LCP can also be used as an internalized external fixation device, which does not require tight bone contact and therefore does not require extensive stripping of the periosteum, and can minimize damage to the periosteum and its blood supply, resulting in better biological healing. At the same time, the screw orientation of PF-LCP can be selected in multiple ways to enhance the grip of bone mass; Moreover, the screw diameter of PF-LCP in the proximal femur is small, and the degree of bone destruction in the proximal femur is light, to avoid avascular necrosis of the femoral head. In the study of Krishna[3] et al. 's treatment of unstable subtrochanteric fractures with PF-LCP, 90% (n=27) of the 30 patients had no postoperative complications, and 6.66% (n=2) of the patients had varus collapse with screw extraction and progression to nonunion. The ability of PF-LCP to restore and maintain post-fracture anatomic and biomechanical stability is worthy of recognition. Wang Xiaohui et al. showed[4] that PF-LCP can be reliably fixed for stable subtrochoteric fractures in the elderly, but its ability to resist axial compression, torsion, and destructive load is significantly weakened compared with PFNA, which is related to the extramedullary eccentric fixation mode of PF-LCP. In general, PF-LCP is a viable option for the treatment of subtrochanteric fractures of the femur, especially for complex and unstable subtrochanteric fractures with poor bone quality or accompanied by lateral wall comminution.

2.2. 95 °Angle plates

Angle plate is a well-established and reliable extramedullary fixation device for subtrochanteric fractures. The surgical indications of the preferred Angle plate for subtrochanteric fractures include: (1) the intramedullary nail insertion site is destroyed; And (2) high-energy subtrochanteric fractures that have been extensively displaced. In Berkes [5]et al. 's study using 95-degree Angle plates to treat proximal femoral fractures caused by acute high-energy injuries, patients achieved a healing rate of 92%, a low rate of secondary surgery, fewer postoperative complications, and no implant failure or infection. However, experimental biomechanical studies by Polat[6] et al. showed poor

biomechanical performance of Angle plates. Therefore, at present, Angle plates are not used as the first choice for the first surgical treatment of subtrochanteric fractures, and are often used in revision surgery for non-union of subtrochanteric fractures. Vicenti[7] et al. used 95-degree Angle plates to treat 15 patients with intertrochanteric and subtrochanteric fractures after nonunion. A follow-up of 6 months showed a high rate of postoperative fracture union, a low incidence of complications, and a good clinical outcome. Han Hongde et al[8]. studied the use of an Angle plate in the treatment of postoperative nonunion of femoral subtrochanteric fractures, and all 20 patients achieved osseous union without internal fixation failure, malunion, or nonunion. Overall, the 95-degree Angle plate remains an excellent surgical option for subtrochanteric fractures, especially in cases of nonunion followed by revision.

2.3. Dynamic Hip Screw (DHS)

DHS was developed for the treatment of intertrochanteric fractures, but it is also widely used for the treatment of subtrochanteric fractures. Wang[9] et al. found that the use of DHS requires the hypermedia trochanteric cortex to remain intact, as in stable Seinsheimer fractures type I and II. In cases where the inferior medial trochanteric cortex is incomplete, such as in unstable Seinsheimer type III and IV fractures, the high-pressure stress on the lateral femoral cortex can be transferred to the lateral plate of the DHS and causing the DHS plate to bend, resulting in implantation failure. Guan[10] et al. also showed that DHS performed poorly compared to intramedullary nails in terms of surgical incision, blood loss, postoperative recovery time, and complication rate. In general, DHS is a good choice for stable subtrochanteric fractures because of its relatively low cost, especially in economically underdeveloped areas. For unstable subtrochanteric fractures, DHS is rarely used.

2.4. Reverse Less Invasive Stabilization System (LISS)

The minimally invasive stabilization system (LISS) was originally developed for distal femoral fractures. In recent years, some scholars have applied it in reverse to the treatment of proximal femoral fracture and achieved certain efficacy. The advantages of this technology may be: (1) LISS plate can have a good attachment to the bone in the proximal femoral region because the proximal femur is consistent with the curvature radius of the plate; (2) screws can be used for multi-angle fixation with bone, which is more conducive to patients with osteoporosis. The study by Wang[11] et al. showed that LISS can provide good stability with good biomechanical effects for stable subtrochanteric fractures (Seinsheimer I to III). Hanke[12] achieved satisfactory results after using the reverse LISS technique in revision surgery for post-operative infected subtrochanteric fractures. However, in a biomechanical study of LISS, Wang[13] et al. found that the axial stiffness of LISS was lower than that of PFNA, possibly because LISS provided insufficient support to the medial cortex of the subtrochanteric bone, thus subjecting it to severe bending stress. In general, LISS is often not an option for initial surgery for subtrochanteric fractures of the femur, but LISS is a reliable option for re-surgery after failure of internal fixation.

3. Treatment options for intramedullary fixation

3.1. Proximal femoral anti-rotation intramedullary nail (PFNA)

The PFNA has a specially designed spiral blade that not only compresses cancellous bone to avoid bone loss but also increases the contact area with bone, thereby enhancing stability and anti-rotation properties. PFNA internal fixation for the treatment of femoral subtrochanteric fractures has the characteristics of short operation time and less intraoperative blood loss. PFNA is a

single screw system, which is more convenient to operate and less damaging to the femoral head and neck. Research by Wang[13] et al. shows that the biomechanical properties of PFNA are excellent in terms of axial stiffness, failure load, and fatigue test cycle. In a study comparing the clinical efficacy of PFNA and DHS in the treatment of subtrochanteric fractures, Guan[10] found that the surgical incision, blood loss, and transfusion time in the PFNA group were smaller than those in the DHS group; The number of intraoperative fluoroscopy was more than that in the DHS group. The PFNA group also had a shorter fracture healing time, an earlier initiation of postoperative weight bearing, and a better postoperative Harris hip score. Hou's study found that fracture reduction during closed reduction of PFNA was relatively difficult, and therefore more intraoperative fluoroscopy was required[14]. However, PFNA is a minimally invasive procedure with less trauma and less intraoperative blood loss. In a study comparing the clinical efficacy of extended PFNA and Gamma3 in the treatment of subtrochanteric fractures, Sun Wei et al[15]. found that compared with Gamma3, the intraoperative fluoroscopy time in the PFNA group was shorter and the amount of blood loss was less, which was statistically significant. This was because the extended Gamma3 nail required multiple repulsions, resulting in increased fluoroscopy frequency and greater intraoperative blood loss. In general, PFNA is a reliable choice for the treatment of subtrochanteric fractures, especially for patients with poor physical conditions who cannot tolerate prolonged surgery.

3.2. Proximal femur combined with Interlocking intramedullary nail (InterTan)

InterTan is a new generation of femoral bone marrow nails. Its main nail has a trapezoidal cross-section at the proximal end, which can effectively increase the intramedullary contact area and improve stability. It adopts the design of a lag screw and compression screw. The combination of two screws and interlock can effectively prevent the rotation of the femoral head and reduce the incidence of postoperative complications, such as nail withdrawal or retraction, head and neck varus collapse, and shortening of the femoral neck. In the process of placing the pressure screw, through the occlusion thread between the pressure screw and the lag screw, the lag screw axis is driven to move, and the anti-rotation stress is transformed into linear pressure on the fracture end so that the anti-cutting performance of the screw can be significantly enhanced so that the joint interlocking between the two screws avoids the "Z" effect[16]. Wu [17]et al. showed that the extended InterTan intramedullary screw fixation was satisfactory in the treatment of Seinsheimer V-shaped subtrochanteric fractures. However, the INTERTAN system, because of its double-nail design, results in more bone loss at the time of drilling, relatively high intraoperative blood loss, and relatively long operative time. Therefore, the InterTan intramedullary nail may be a better choice for younger patients with better physical conditions and more demanding conditions.

3.3. Long or short intramedullary nailing

In subtrochanteric fractures, intramedullary staples are considered the gold standard. When short intramedullary nails are used to treat subtrochanteric fractures, the medial cortex lacks support. In addition, the distal locking screw hole is close to the fracture line and there is a risk of new fractures. In the meta-analysis by Viberg[18] et al., for subtrochanteric fractures, the postoperative reoperation rate in the short intramedullary nail group was 8.4%, while that in the long intramedullary nail group was 4.0%. Long intramedullary nails had a lower postoperative recurrence rate for subtrochanteric fractures, and the difference was statistically significant. It was also found that patients treated with short intramedullary nack for subtrochanteric fractures had a higher proportion of periprosthetic fractures. Linhart[19]'s biomechanical study of short and long intramedullary nails showed that there was no difference in overall structural stiffness between short and long PFnas,

with increased fracture space displacement compared to long intramedullary nails. It has also been shown[20] that long-headed intramedullary nails with at least two distal locking screws are preferred for subtrochanteric fracture fixation; For high subtrochanteric fractures, short intramedullary nails are also a viable option. Therefore, we suggest that long intramedullary nails should be the first choice in the treatment of femoral subtrochanteric fractures.

4. Assistive techniques: limited open reduction combined with cyclization

Postoperative complications such as fracture dislocation and nonunion are not uncommon after the treatment of subtrochanteric fractures with intramedullary nailings. At present, limited incision and insertion of a circumferential ligature are often used in clinical practice to reduce the incidence of complications after intramedullary fixation of subtrochanteric fractures, because the fracture can be better reduced, the fracture space is smaller, and the medial support can be better restored, and the anatomic reduction can be maintained through ligature fixation, which can significantly improve the quality of fracture reduction. Panteli's [21] study showed that the treatment of subtrochanteric fractures with a circumscribed ligature had a lower rate of nonunion compared to closed reduction alone. Hoskins[22] et al. 's study also showed that the use of circumferential ligature has a significant advantage in the precision of fracture reduction, and for patients with Seinsheimer type 4 or 5 caused by high-energy trauma, the use of circumferential ligature can significantly reduce the rate of postoperative nonunion. Previously, it was thought that the use of a coring wire resulted in an increased risk of strangulation necrosis of the femur, leading to failure of healing. However, Forch[23] et al. 's experiments with different models of the femur using ligature showed no associated damage to the blood supply in human cadaver femurs; For live dog femurs and live horse femurs, periosteal blood supply remained unimpaired. This was further confirmed by Lenz[24] et al. 's in vitro studies using human bone, where no periosteal compression was observed with circumferential ligations. At the same time, Panteli[21] believes that limited open reduction of subtrochanteric fractures does not increase the risk of deep infection in the operative area. However, an increased risk of superficial intraoperative infection was associated with an improved rate of blood transfusion within 48 hours of surgery. Therefore, open reduction is not necessary for fractures that can be fully reduced by closure, as this may lead to an unnecessary risk of complications. In general, for complex subtrochanteric fractures, the combination of limited open reduction and the use of a circumventing wire may result in better surgical outcomes.

5. Conclusion

For patients with subtrochanteric fractures who are tolerant to surgery, try to operate early with internal fixation and early functional exercise. Subtrochanteric fractures can be treated with either extramedullary or intramedullary methods. Devices used for extramedullary fixation include compression locking plates at the proximal femur, 95 ° Angle plates, minimally invasive fixation systems, and dynamic hip screws. Extramedullary fixation is still widely used for the surgical treatment of subtrochanteric fractures of the femur due to its low cost and the familiarity of extramedullary fixation with orthopedic surgeons. For complex and unstable subtrochanteric fractures with poor bone quality, compression locking plates at the proximal end of the femur are a viable option. For patients who have failed intramedullary nailing, revision is often done using a 95 ° plate or a minimally invasive fixation system. However, extramedullary fixation has a high rate of nonunion, so we do not recommend extramedullary fixation as a primary surgical option for subtrochanteric fractures. The commonly used methods for intramedullary fixation include PFNA, Intertan, etc. Intramedullary fixation is more in line with the force line, conducive to load transfer, and more in line with biomechanical requirements. In addition, the intramedullary fixation system is

less invasive, less intraoperative blood loss, and more conducive to early rehabilitation training of patients. Therefore, at present, internal fixation is the "gold standard" in the treatment of femoral subtrochanteric fracture. PFNA has the characteristics of simple operation and less blood loss, which is suitable for patients with poor physical conditions and who can not tolerate long-term surgery. InterTan internal fixation has fewer postoperative complications and is suitable for younger patients with better physical conditions and higher requirements. At the same time, for complex subtrochanteric fractures of the femur, closed reduction alone is often unable to achieve good reduction, and limited incisions are required to assist with circulation to achieve anatomic reduction of the fracture. In general, due to the special anatomical structure of the subtrochanteric region, there is still no consensus on the treatment of subtrochanteric fractures, and the surgical methods are varied. In our clinical work, we need to conduct adequate preoperative evaluation of patients to select the appropriate treatment plan.

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