

Intramedullary nailing of humeral fractures

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Abstract

Fractures of the humerus present about 3 % of all fractures. The majority are closed fractures (85-90 %). In the last two decades an important progress in conservative and surgical treatment of the humeral fractures was achieved. Surgical treatment of humeral fractures was enhanced by the development of new minimally invasive surgical procedures with biologically more appropriate osteosynthesis and better results. Nevertheless, most humeral fractures are still treated conservatively. Detailed knowledge of the region's anatomy, careful study of the fracture type and patient's lifestyle and expectations should be considered in the decision for the type of treatment.

Introduction

Humerus is a long tubular bone that contacts the scapula in the shoulder joint and the ulna and the radius the elbow. The diaphysis goes from the surgical neck and from the growing of the large pectoral muscle to the condyles. The upper two thirds of the humerus are of cylindrical shape in the cross section, and the distal third is triangular. Muscles around the middle of humerus are divided into the front - flexor compartment and the back - extensor compartment. They are separated by the medial and the lateral inter-muscular septum. *M. biceps*, *m. brachii*, *m. coracobrachialis*, *m. brachialis*, *art. and v. brachialis*, *n. medianus*, *n. musculocutaneus* and *n. ulnaris* are in the front. In the back, we can find *m. triceps brachii* and *n. radialis*.

The inner part of the humeral cortical bone is supplied by *art. nutritia*, a branch of *art. brachialis*. It enters the diaphysis at the medial side, between the medial and the distal third. It splits into the ascendent and descendent branch inside the medullary canal. Some individuals also have a special nutritive branch that enters the canal in the beginning of the radial drain. Some food is also carried by metaphyseal arteries that enter the canal through the growing of articular ligaments. The outer part of cortical bone is supplied with food by periost vessels.

Humeral fractures are caused by action of direct or indirect forces. The usual causes are falling on the arm, traffic accidents, and direct impacts (e.g. in fights). Some cases describe fractures caused by sudden muscle contraction in baseball players. Humeral fractures are divided based on AO typology.

The clinical picture shows a swelling, deformity of the humerus, pathological flexibility and crepitation can be felt, the patient is experiencing pain. When examining the patient, we must pay attention to vascular and nerve damage and to the possibility of compartment syndrome.

Methods of conservative treatment

Most medial humeral fractures can be treated conservatively. Over 90% of cases repair successfully within 8 to 10 weeks. Deviations that we allow, are valgus at an angle up to 20°, bending

forward or backwards at an angle up to 20°, axis irregularities at an angle up to 30°, and shortening of the upper extremity for up to 3 cm, as deviations within these limits – together or individually – do not severely affect the final result of treatment.

Techniques of conservative treatment of humeral fractures are:

- a burdening plaster sleeve,
- thoracobrachial cast or brace,
- U-shaped brace,
- Velpoux-Dessault plaster band,
- functional brace,
- Gilchrist band.

Methods of operative treatment

Surgical fixation of humeral fractures can be performed with:

- plates and screws (4.5 mm wide DCP, 4.5 mm narrow DCP, 4.5 mm narrow LC DCP plate),
- wires, sticks and nails (after Rush, Hackenthal, Ender, Prevot, Seidel, or with locking intramedullary nail)
- an external fixator.

Intramedullary nailing of humeral fractures was developed on the basis of intramedullary fixation of femoral and tibial fractures. The use of classical Kuntschner nail for fixation of humeral fractures often led to complications; therefore this method is not often used. The use of elastic intramedullary sticks, wires and nails without locking screws (Rush, Ender, Hackenthal, et al.) did not bring satisfying results either because axis and longitudinal stability were not provided. In the 1970's, Derweduwen designed first locking intramedullary nails to fast the particles. In the late 1980's, Seidel invented a nail with locking screws only at the proximal part of the nail, for the purposes of fixation of humeral fractures. In the distal part, he designed special wedges, but they only ensured 5% rotation stability in comparison to the healthy extremity. In 1991, Russel and Taylor introduced an intramedullary nail with distal and proximal locking screws. The latest intramedullary nails have three locking screws (in different directions) at both sides.

Indications

The humeral intramedullary nail is used in:

- open fractures of I, II, and III A level (by Gustilo-Andersson). We normally use reamed or non-reamed nails. III B or C level open fractures are usually stabilized with an external fixator.
- fractures with associated vascular or nerve injuries. The plate is more appropriate for osteosynthesis because it allows revision and fixation at the same time (through the same incision). The risk of radial nerve injury is the highest in Holstein-Lewis fractures. It lies between the medial and the distal part of the humerus, where the nerve goes through the lateral intramuscular septum. It usually leads to neuropraxis or axonotmesis. In 90% of cases,

the nerve functions recover completely within 3 to 4 months. If we stabilize the fracture with an intramedullary nail, we must open the area around the fracture and examine the *n. radialis*. That takes away all the advantages of biological osteosynthesis with a nail.

- pathological fractures. Usually intramedullary nails are used. Before operative treatment, we must determine the type and the area of the process (multiple, solitary metastasis).
- instable fractures.
- humeral fractures in poly-traumatized patients. Considering the associated injuries, the patient's general condition and the surgeon's experiences, we decide either on a non-reamed intramedullary nail or on an external fixator.
- fractures that cannot be repositioned without surgery. We can choose between a plate and intramedullary nail. If secondary paralysis of *n. radialis* occurs after reposition, we cannot use a nail for stabilization because there is a possibility that the nerve is trapped between the particles, and inserting the nail could damage it additionally.
- fractures that result in delayed reparation or even pseudoarthrosis. For better results, fixation with a plate is often associated with spongioplastic (autologue bone transplant). If we use an intramedullary nail, we ream the medullary canal and insert a nail with minimally 4 locking screws to provide sufficient rotational stability. We also perform a bone transplant through an additional mini incision.
- both-side humeral fractures.
- fractures that reach into the joint. We perform osteosynthesis with plates and screws.
- multi-layer and transversal fractures can also be treated surgically. We normally use intramedullary nails.
- humeral fractures associated with burns.

Contraindications

Contraindications that speak against the use of intramedullary nailing are:

- presence of open growth cartilage in children,
- infection,
- proved over-sensibility to metals,
- inborn or acquired irregularities of the humerus (closed medullary canal, improperly repaired fractures, ...),
- solitary carcinoma metastasis,
- III B or C open fractures.

The distinction between antegrade and retrograde intramedullary fixation depends on the position of the entry into the medullary canal during fixation. We separate the reaming and the non-reaming technique, depending on the method of placing the intramedullary nail and on the characteristics of the nail. Each of the methods has certain advantages and disadvantages.

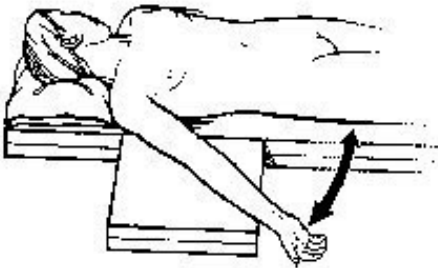
Antegrade intramedullary fixation

This method of fixation is appropriate in cases when the fracture lies approximately 2 cm above the surgical neck of the humerus at the upper side and 3 cm above fosa olecranon at the bottom side. The patient is under general anaesthesia, lying on the back at the edge of the operative table, which is preferably X-ray transparent (picture 1).

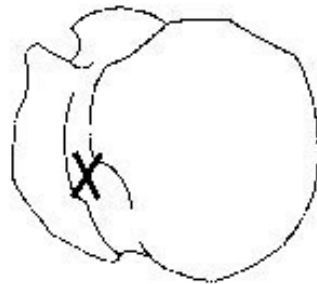
The patient's head is placed into a specially designed pillow, turned to the opposite side of the fractures extremity. Because of pulling, aimed at repositioning the particles, it should be additionally fastened to the table with a band. The shoulder joint must be loose to allow X-ray films in two projections. After the pre-operative preparation of the skin area from fingers all the way to the chest wart and after sterile covering of the surgical field, we place the injured extremity to a sterile covered table. We can choose the proper length and diameter of the nail before surgery with the help of the X-ray pictures of the healthy extremity and with the use of a special measure, included in the instrumentary.

First we make a short incision (4 to 5 cm long) from the edge of the acromion over the middle of the greater tuberosity in the distal direction. After cutting through the skin and after hemostasis, we cut the fascia and split the deltoid muscle fibres longitudinally, but only in the length of app. 4 cm so we do not damage *n. axilaris* which surrounds the humeral neck from the posterolateral direction. Then we feel humeral tuberosity, and cut the rotator cuff longitudinally between the anatomic humeral neck and greater tuberosity with a scalpel. We make the incision as medially as possible to avoid the area of non-vascularized rotator cuff. We enter the medullary canal at the edge of the articular cartilage with a bent bodkin (picture 2), controlling the entry with an image intensifier. This ensures that the entry lays at the extension of the extension of the medullary canal in both projections, and eliminates the risk of additional fractures at the entry. Further procedure depends on the type of nail we decided to place.

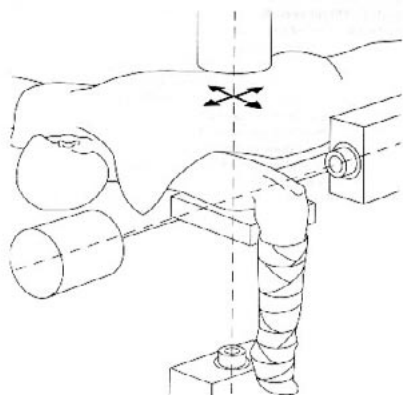
Nails vary in diameter (6, 7, 7.5, 8, 9, 9.5 mm); they are either full or hollow. The latter are usually placed after reaming the medullary canal. The full nails can be placed without reaming. Before reaming, we usually guide a wire with a thickened end into the canal, about 2 cm proximally to olecranon fosa into the centre of the distal particle. We then gradually ream the medullary canal to a diameter that is 0.5 to 1 cm wider than that of the chosen intramedullary nail. The humerus is very fragile and has very thin walls in comparison to the femur or the tibia, therefore we must ream very carefully. We must avoid reaming in the area of the particles (cominuted fractures), because additional fractures might occur or blood circulation could be severely damaged. Reaming is usually required in young patients with firm spongy bone and in patients with narrow medullary canal. In other cases, the intramedullary nail can usually be placed without reaming, except to expand the entry.



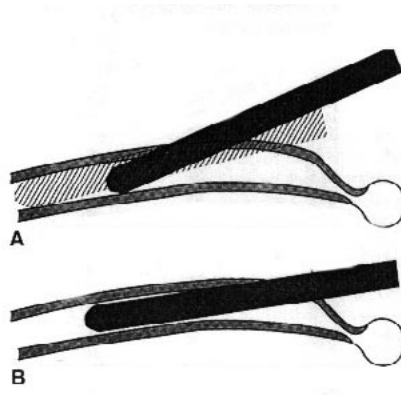
Picture 1. Patient's position during antegrade intramedullary fixation of humerus.



Picture 2. Entry for the antegrade nail. View from above.



Picture 3. Patient's position during retrograde intramedullary fixation of humerus.



Picture 4. Entry for the retrograde humeral nail.
Legend: A – supra-condylar access, B – access through the upper edge of fossa olecranon.

If we determine the length of the intramedullary nail intra-operatively, we need a special measure and the whole process is monitored on an image intensifier. The determined length also equals the original length of the guiding wire (with the thickened end), that is 700 mm; minus the length of the part of that wire that did not fit into the medullary canal during reaming.

After replacing the guiding wire with a wire without a distal thickening, we place the intramedullary nail into the canal with gentle circular moves (no hammering is involved). We sink the nail under the edge of corticalis at the entry. Distally, the nail is placed 1 to 2 cm above olecranon fosa. We lock the proximal cortical locking screw with a special handle, at an angle of 0 to 20° from the posterolateral to anteromedial direction. We determine the length with a measure.

Next, we stretch the patient's arm and put it on a sterile covered table. We display the oval distal locking opening on the image intensifier. In this area, we make a small incision at the lateral edge of the biceps. After moving the muscle fibres, we insert the handle, ream the opening and fasten the distal locking screw. The whole procedure is displayed and controlled with the image intensifier at all times. This is how we place the intramedullary nail from the front side of the arm. Another way is from the back, through the triceps. After bathing and draining the surgical wound, we carefully sew together all layers of soft tissue and the skin.

Retrograde nailing of humeral shaft fractures

This method is used in cases when the fracture lies in the medial or lower third of the humerus. Its main advantage is the fact that the entry lies outside the shoulder joint, meaning there is no risk of damaging the rotator cuff and the subacromial area. The patient is laid on his front. The injured extremity is loose, placed on a special X-ray transparent handle (picture 3). In this position, correct reposition in all three directions is possible.

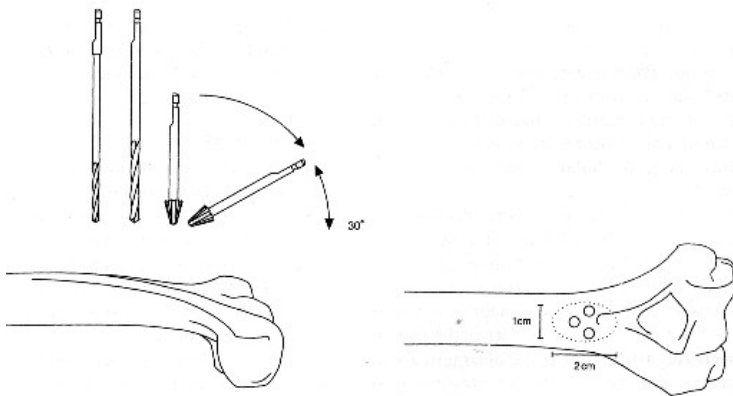
After pre-operative preparation, we make an incision of about 8 cm from the top of the olecranon in the proximal direction at the back side of the middle of the humerus. Then we split the *n. triceps* longitudinally. We must keep in mind the possibility of *n. radialis* passing this area, although it normally goes through the lateral intramuscular septum and around the humerus between the medial and the distal third. Two entries into the medullary canal have been described so far:

- supracondylar entry lying 2 to 2.5 cm above fosa olecranon,
- entry through the upper edge of fosa olecranon.

Both entries lie outside the joint. We must be careful not to cut through the articular capsule (picture 4). How we enter the medullary canal depends on the available instrumentary. First we ream through the cortical part of the humerus with a 3.2 mm drill at an angle of 30°. Then we use the 4.5 mm drill, the entry is expanded with a pointy drill. When reaming, we gradually reduce the angle to make an oval entry, 1 to 2 cm large (picture 5). It is important that we make a drain in proximal corticalis to facilitate the placement of the intramedullary nail. The next step is deciding on the length and the diameter of the nail, which has already been described. To avoid any additional fractures during the placement of the nail, we ream the entry to a diameter that is 1 to 2 mm wider than the diameter of the chosen nail. The nail can be placed with or without reaming the medullary canal. The top of the nail should be at the same level as the surgical neck.

Placing the distal locking screw with the help of a handle is usually not problematic. We insert the proximal locking screw under control of an image intensifier, with the free locking technique or with the use of an X-ray transparent added piece in the posterolateral-antero-medial direction. The area where the locking screw can be placed safely into the proximal part of humerus is presented in picture 6. We must be careful not to injure the *n. axilaris*.

The structure of different types of intramedullary nails allows placement of various locking screws at different angles for different purposes (static, dynamic screws). Some nails can also encourage charging of particles or compression of non-unions.



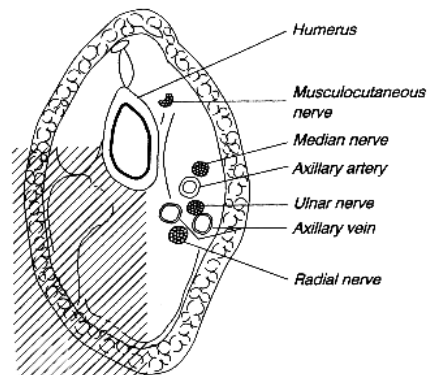
Picture 5. Entry points in retrograde method.

To provide peri-operative antibiotic protection, we prescribe first or second generation cephalosporines in a one-time dose. We remove the drainage in the second post-operative day. After surgery, no additional immobilization is normally required. We can start exercising the shoulder and the elbow just a day or two after the operation. We place the shoulder joint on a motorized brace during exercise. When the pain weakens a bit, we encourage the patient to do active exercise (during day 4 and 7 after the operation). To reduce the formation of myositis ossificans, the patient is only required to do active exercise for the elbow. If the osteosynthesis is not firm enough, we immobilize the injured extremity for a week in a Gilchrist band. After the swelling is reduced, we can additionally immobilize the humerus with a brace. It is important that the formation of callus is visible in the X-ray pictures before we advise the patient to perform any weight-bearing. Heavy burdens should be avoided until the reparation is complete. Patients are hospitalized for 10 days in average. Before discharging the patient from the hospital, we must film a control X-ray picture of the injured extremity. Further treatment involves physical therapy. Control X-ray pictures are made in the second and the fourth post-operative week, and then in the third post-operative month. After that, we check the patient's condition once a month until complete reparation. We normally do not remove the intramedullary nails, except when infections or the compartment syndrome occur or if we must perform another operation.

Complications

We can distinct between intra- and post-operative complications, and early and late complications. *Intra-operative* complications are:

- additional fracture of the humerus during intramedullary nailing,
- secondary paralysis of the *n. radialis* (in 4 to 6 % after intramedullary nailing, 3 to 29 % when we use a plate for fixation),
- difficulties with the placement of the intramedullary nail or the locking screws,
- improperly chosen intramedullary nail (in length or diameter),
- injury of *n. axilaris*,
- secondary movement or insufficient reposition,



Picture 6. Area of safe placement of proximal locking screw (lined).

- insufficient fixation (esp. in older patients),
- fat embolism.

Post-operative complications are:

- infection of the operative wound at the medullary canal,
- bending or fractures of the intramedullary nail or the locking screws,
- additional movement of the particles,
- compartment syndrome,
- avascular necrosis of humeral particles,
- movement of the nail which leads to the occurrence of the impingement syndrome (up to 40 % of cases, esp. in senior patients with osteoporosis),
- delayed union and pseudoarthrosis (in 10 % of cases, according to some authors in 20 to 30 % of cases after IM nailing, and in approximately 7 % of cases where a plate was placed). A delayed union is defined as a fracture that has not repaired after 4 months of treatment, and a non-union/pseudoarthrosis is defined as a fracture that has not repaired after nine post-operative months.

Pain in the shoulder joint at limited rotation (in 4 to 5 % of cases, whereas some authors claim that up to 30 % of patients suffer constant pain after placement of a locking antegrade intramedullary nail). Problems may occur as a consequence of damage on the rotator cuff, impingement syndrome, and heterotopic ossification. Evaluating the final success of the operation involves the evaluation of flexibility (abduction, adduction, bending, and stretching of the shoulder joint). The score is expressed with the ROM (*range of motion*) index. Rommens states that in almost 90 % of patients ROM decreases for less than 10 % after the operation, and a decrease within that range is evaluated as excellent result. In 8.8 % of patients the ROM index diminishes for 10 to 30 % after the operation, and in 1 to 2 % of patients the result is very low, that is the ROM index decreases for over 30 %. A similar index is used to evaluate the flexibility of the elbow after retrograde intramedullary nailing of humeral fractures. Results given in Rommel's studies are similar to those of antegrade nailing.

Reactions of increased sensitivity to osteosynthetic material.

Discussion

Currently the main debate in literature is about the choice of the fixation technique (use of intramedullary nails or plates) and about reaming the medullary canal. The main advantages of the intramedullary nail are that it allows osteosynthesis without opening the hematoma around the fracture area and without additional damage to the circulation through the particles, and the principle of a minimally invasive technique requiring a small incision which gives better results from the cosmetic point of view. The operation lasts less (1 hour in average in fresh fractures and 1.5 hour in pseudoarthrosis). The reparation process lasts 8 to 10 weeks in fresh fractures and approximately 14 weeks after operative treatment of non-unions. Blood transfusion is normally not required after the operation. The surgical technique is easier to perform; there is less damage to *n. radialis*. The main disadvantage is lower axis stability which leads to a higher share of non-unions. This will probably change with the development of new types of nails with more locking screws. The main advantage of osteosynthesis with a plate is the

possibility to examine and, if necessary, operate on the injured nerve at the same time during fixation. The patient and the surgical team are not exposed to radiation.

Unlike in tibial or femoral fractures, the positive biological effect that reaming is supposed to have on the reparation in humeral fractures cannot be supported with clinical results. Reaming is usually only necessary in treatment of younger patients with firm spongy bone and with a narrow medullary canal. Reaming expands the contact surface between the nail and the endosteal surface and therefore allows a more stable fixation. But even minimal reaming affects the endosteal circulation and causes thrombosis of the food-supplying arteries. Literature describes cases of avascular necrosis of particles during reaming in cases of multi-layer humeral fractures; therefore the use of non-reamed intramedullary nails is favourable. On the other hand, reaming accelerates blood circulation through the periosteal veins and through the whole arm. But as the reamed intramedullary nail is in close contact with the endosteal surface, endosteal circulation is strongly affected which means that its renewal after placement of a non-reamed intramedullary nail is much faster and far better than after reaming.

Conclusion

Humeral fractures can be treated successfully both surgically and conservatively if the treatment is properly pre-meditated. The initial excitement over the intramedullary fixation was more and more pushed aside by the success of modern AO biological osteosynthesis with plates and screws. But the development of new intramedullary nails with more locking screws could lead to better results and less complications after intramedullary fixation of humeral fractures in the future.

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