TRAUMA

Humeral nails: When to choose what and how to use

Christos Garnavos

Orthopaedic Department of "Evangelismos", General Hospital, 8 Londou St, Glyfada 16675, Athens, Greece

Summary Intramedullary nailing of the humerus is controversial. This may be partly because of the complicated anatomy and the unique biomechanical characteristics of the arm, and also because the principles and nail designs used for the treatment of femoral and tibial fractures have been directly transposed to this location. Over the last few years there have been several reports on the indications for humeral nailing, timing of the procedure, surgical technique, and nail design. As a result, surgeons witnessed the appearance of a wide variety of humeral nails with different biomechanical properties and implantation techniques, reflecting the disputes concerning intramedullary nailing in the humerus. In this article it is proposed that humeral nails should be categorised into two distinct groups (fixed and bio), according to their main characteristics and their use must follow guidelines that will be outlined, paying respect to the fracture pattern and location. Other issues such as the timing of surgery and the role of reaming are also addressed in an effort to further improve the results of intramedullary nailing in the humerus. © 2005 Elsevier Ltd. All rights reserved.

Introduction

Indications that are generally accepted for surgical treatment of an acute humeral fracture include multiple injuries, bilateral fractures, pathological fractures, floating elbow, brachial artery injury, brachial plexus palsy, open or segmental fractures and inability to maintain fracture alignment with functional bracing. However, over the last few years intramedullary nailing of humeral shaft fractures has gained popularity amongst surgeons, particularly with the trend for developing treatment modalities that can be minimally invasive with low morbidity, providing simultaneously rapid recovery and prompt return to work and everyday life activities. Intramedullary nailing satisfies these criteria for diaphyseal femoral and tibial fractures but when we deal with humeral shaft fractures it seems that there is still confusion about the basic principles. Controversy exists as to why one should choose an intramedullary nail in preference to another implant, the timing of surgery, nail design selection, surgical technique

*Tel.: +302109628172. E-mail address: garnavos@eexi.gr.
(antegrade/retrograde–reamed/unreamed) and whether to bone graft or not. Being influenced by the success of intramedullary nailing in the femur and tibia, surgeons unsurprisingly transposed their knowledge and experience with the technique for treating humeral shaft fractures. However, in general, the unique anatomy and biomechanical characteristics of the humerus and its adjacent joints were overlooked. After numerous proposals concerning the design and capabilities of the “ideal” humeral nail and unconvincing debates about the “best” surgical technique, it seems that there is still doubt about “when to choose what and how to use it”.

Classifying humeral nails

Despite many differences in design and intended surgical technique, humeral nails can be grouped generally into: (a) those offering strong mechanical fixation to the fracture (fixed-nails) and (b) those paying more attention to the biology and the anatomy of the arm (bio-nails), at the expense of rigidity of the fixation.

“Fixed” humeral nails

Nails in this category are made of either stainless steel or titanium, so their stiffness varies (Table 1). The common characteristic is that locking screws provide both proximal and distal interlocks and for that reason axial and rotational stability at the fracture site are good (Fig. 1). Because of the interlocking capabilities, location of the fracture within the diaphysis is not an important issue for the selection of surgical technique. In general, fixed-nails can be used with both antegrade and retrograde techniques (the decision mostly depends on the surgeon’s preference), without the location and type of fracture playing an important role (Fig. 2). Problems and complications that occur are mostly related to the complex anatomy and individual biomechanical characteristics of the humerus.

During antegrade insertion

With a fixed-nail, the deltoid and rotator cuff are injured by the surgeon’s knife, the penetrating awl,
the reamers (whenever used), and by the nail, the drills and locking screws.36–40

The inevitable penetration of the deltoid muscle for the insertion of the proximal locking screws adds to the injury in the area. Furthermore, drills and screws can injure the axillary nerve and the long head of biceps tendon.18,41–45

In addition, drilling and screw insertion for the distal interlock bears the significant risk of injuring the radial or the lateral cutaneous nerve of the forearm at the level of the elbow.6,9,18,29,35,42,46–49

During retrograde insertion

With a fixed-nail, fractures at the supracondylar area have occurred as result of the eccentric insertion of the nail, the narrow humeral canal and the stiffness of the nail (Fig. 3).8–10,18,36,48,50 In addition, the axillary nerve is at risk by the locking screws used for locking the nail at the proximal end of the humerus.41

Both antegrade and retrograde techniques

Fixed-nails share the problem of difficult and time consuming insertion of the locking screws at the tip of the nail. This is achieved with either the free-hand technique, which in the humerus may be particularly hazardous and sometimes difficult. This can be because of the inability to obtain an easy lateral view with the image intensifier or because of targeting devices that provide questionable reliability without eliminating the danger of injury to important vulnerable soft tissues (Fig. 4).6,9,18,29,35,41–43,47,49,51

Fixed-nails were used in the humerus, in the first instance, because of the excellent results produced by (fixed) intramedullary nailing of the femur and tibia. Problems related with their use in the arm were not foreseen. After the emergence of problems and complications directly related to the very techniques used to obtain stability (reamers, drills, locking screws), an important issue was raised: does the humerus need absolute stability (or at least as stable as is provided in the femur and tibia by a nail) or could a less stable environment suffice, thus offering the opportunity for avoidance
of some complications related to technique? In a recent article Perren (2002) states that the aim of modern fixation of long bone fractures is to "...produce the best biological conditions for healing rather than absolute stability of fixation and this approach has been shown to give early solid union". If we bear in mind that functional bracing (still treatment of choice for acute humeral shaft fractures) does not provide significant rotational or axial stability at the fracture site in the humerus, it becomes apparent that in the management of humeral shaft fractures absolute stability may not be necessary. Therefore, while the amount of stability required for uneventful healing of humeral shaft fractures remains to be defined, it could be stated that recent research and experience gained from the use of functional bracing have shown that humeral fractures can heal well with "adequate" or "relative" stability. The appearance of bio-nails is based on this statement.

"Bio" humeral nails

Nails in this category are commonly made of either stainless steel or titanium (Table 2). Their shared characteristic is the avoidance of locking screws, at the tip of the nail. A unique, for each nail, feature or technique provides the "relative" stability needed for the fracture healing process. For example, the Marchetti nail consists of 4 or 5 spreading rods that abut firmly against the endosteum beyond the fracture and resist rotation (Fig. 5). Spreading wires are also used by the Halder nail. The Fixion nail expands and incarcerates within the humeral canal. The True-Flex nail is fluted (star shape cross-section) and, by selecting

**Figure 4** Failure of a targeting device to guide the distal screw properly.  
**Figure 5** Correct use of a retrograde bio-nail.
the appropriate nail size, the flutes resist rotation beyond the fracture (Fig. 6). Despite the different ways of achieving distal interlock, the common theme is avoidance of the use of locking screws. To eliminate the possibility of damage to the soft tissues around the shoulder joint, Marchetti-Vicenzi and Halder nails are inserted only with the retrograde technique. True-Flex nails inserted with the antegrade technique do not use transverse locking screws for the proximal interlock (Fig. 7).

Problems and complications that have occurred with bio-nails are mostly related to their unique features but may also be the result of incorrect use of each nail. For example, the use of Marchetti-Vicenzi and Halder nails has been complicated by perforation of the humeral head by the expanding rods, while removal of the Marchetti-Vicenzi nail has been occasionally reported as difficult or impossible.\(^5\)\(^{,11,50}\) Complications of other bio-nails include unacceptable alignment of the fracture and nail migration.\(^14\)\(^{,36,56}\) Iatrogenic fracture or fracture extension and comminution at the supracondylar area have been reported sporadically during retrograde bio-nailing.\(^11\)\(^{,36,50}\) Union rates and functional outcomes after bio-nailing appear satisfactory and similar to those obtained after fixed nailing, as reported in independent, non-comparable studies.\(^4\)\(^{,12,13,50,54,56-58}\) However, the lack of prospective comparable studies must be stressed.\(^11\)

The quality of the fixation offered to the fracture site by bio-nails depends mainly on the features and design of each nail, as well as on the surgical technique and the fracture configuration and location. By definition, bio-nails offer an adequate interlock at the end closest to the insertion point whilst the tip interlock is achieved by nail design features and capabilities (shape, expansion, spreading rods, etc.). A general principle that should apply in bio-nailing, is that as much length of the nail as possible should be within the bone segment that is not the segment bearing the insertion site, to provide better stability. In this way, the spreading rods of the Marchetti nail have more room for expansion, and there is more contact surface with inflating or fluted nails, etc. Therefore, the advantages offered by the design of

---

**Figure 6** Correct use of an antegrade bio-nail.

**Figure 7** Avoidance of transverse-locking screws proximally during antegrade bio-nailing. The proximal interlock is provided by other means.
a bio-nail function better if the fixation is performed from the short to the long segment. This general rule has been recommended for fixed nailing but its application to bio-nailing is unequivocal (Figs. 8 and 9). Conclusively, a key point for humeral bio-nailing is that fractures of the proximal humeral diaphysis are better treated with antegrade technique while fractures of the distal humeral diaphysis are better treated with retrograde technique. However, because of their design, some bio-nails can be inserted with either the antegrade or the retrograde technique but not with both (e.g. Marchetti-Vicenzi retrograde, True-Flex antegrade). This drawback may be responsible for some of the problems encountered with their use, such as inadequate fixation of proximal humeral fractures treated with the retrograde Marchetti-Vicenzi nail (where the rods do not have enough canal length to expand adequately) (Fig. 10) or unstable fixation of distal humeral fractures treated with the True-Flex nail (where there is not enough length of the humeral canal for the fins to engage and stabilise the distal segment) (Fig. 11). Fracture location has not been the inclusion (or exclusion) criteria in any of the studies dealing with bio-nailing, which means that fracture location has not been, so far, a criterion for determining either the use of a specific bio-nail or the performance of a specific operative technique (antegrade or retrograde), an issue that authors may need to address in future studies.

Reaming

Reaming is recommended with several fixed and bio nails, copying the current practice used for intramedullary nailing of femoral and tibial fractures. However, the concept that use of a broader nail provides stronger and more stable fixation whilst allowing the use of wider stronger locking screws leading to safer/faster mobilisation, weight bearing, and fracture union may not hold true in the humerus, as we are dealing with a non-weight bearing bone.

During antegrade nailing

Reamers could add to the damage of the rotator cuff directly, as mentioned. It has been reported...
that reaming of the humeral canal can cause heat-induced segmental necrosis with adverse consequences for fracture healing.\textsuperscript{38,62} Also, by-products of reaming could accumulate underneath the rotator cuff (as they are deposited during withdrawal of the reamers) and play a role in the pathogenesis of pain and post-operative stiffness of the shoulder joint.\textsuperscript{39} Unfortunately, there are no studies comparing the outcomes of reamed and unreamed antegrade humeral nails to support this hypothesis. Finally, reaming could damage the radial nerve directly if the fracture is not reduced accurately and is located at the spiral groove, where the nerve is close to the bone.\textsuperscript{36}

**During retrograde nailing**

Careful reaming does not appear to cause any additional problems, provided that thorough washing of the supracondylar area is performed at the end of the procedure. Contrary to what was said about antegrade nailing, reaming might be necessary during retrograde nailing, to enlarge the (usually narrow) distal humeral canal, thus facilitating nail insertion and reducing the possibility of iatrogenic fracture at the supracondylar area.\textsuperscript{63} However, although it has not been reported so far, similar complications that occur with insertion of a wide nail to a narrow humeral canal (e.g. supracondylar fracture) could happen with the use of too big reamers. Also weakening of the humeral canal with too much reaming could lead to subsequent stress fracture.
Timing

Over the last two decades intramedullary nailing has been established as the treatment of choice for diaphyseal fractures of the femur and tibia, regardless of whether surgeons were dealing with recent or non-recent fractures. In the lower limb the method has gained acceptance because of (a) the optimal mechanical environment that is engendered for the healing bone (internal splintage of the fracture and weight shearing) (b) the early mobilisation and weight bearing that promotes fracture healing and early return to pre-fracture activities and (c) the complementary role of reaming, that facilitates insertion of stronger nails (with better mechanical properties thus permitting early weight bearing) and promotes fracture healing in non-acute fractures, delayed unions and pseudarthroses by internal debridement and creation of osteogenic byproducts around the fracture/pseudarthrosis site.

None of these factors can be used in a similar manner in the humerus: the superior mechanical properties offered by intramedullary nails to fractured long bones of the leg are of little value in the arm, as the long bones of the upper limb do not bear the body weight. Reaming of the humeral canal cannot be recommended in the humerus for reasons that have been explained previously and dynamisation of the fracture site cannot effectively happen (non-weight bearing bone). However, fresh fracture haematoma, which is present after all recent fractures, plays an important role in the healing process and it may be the only biological factor assisting intramedullary nailing in the humerus.

As a result, one could expect a better outcome from the use of intramedullary nails in fresh fractures and less favourable as time goes by. Consequently, in the humerus, better fracture healing and good functional results accompany early nailing and for that reason intramedullary splintage must be considered as a primary treatment option.

In cases of delaying unions and pseudarthrosis intramedullary nailing can be a treatment alternative (alongside compression plating), but bearing in mind the analysis above, thorough debridement and bone grafting should be done to the fracture site. Compression of the ununited fracture by either interfragmentary wires or by the compression mechanism offered by some nails (AO, T2) could contribute to better results.

Discussion

In the surgical management of humeral shaft fractures intramedullary nailing could be the treatment of choice, offering minimal morbidity and a low complication rate. However, nailing of the humerus must be distinguished from similar techniques used for the fixation of femoral and tibial diaphyseal fractures. The humerus has unique anatomical and biomechanical characteristics, so intramedullary nailing should be adapted and modified accordingly. The present study proposes a categorisation of humeral nails into fixed and bio. Knowledge of the differences between the two groups could help towards the selection of the most suitable nail for each fracture, according to fracture "personality", the required nail capabilities and the corresponding surgical technique.

As a general rule fixed-nails can be used for the osteosynthesis of any diaphyseal humeral fracture and selection of the antegrade or retrograde technique is based upon the surgeon’s preference and experience. On the contrary, with bio-nailing antegrade or retrograde technique must be decided, taking account of fracture location, as the nail should be inserted from the shorter to the longer segment to offer better fracture stability.

This proposed classification could define a framework for organising objective clinical and biomechanical studies in the future. In recent studies, "humeral nailing" is compared with other treatment modalities regardless of the nail used in the study. In this way, results (favourable or not) reflect on the specific humeral nail used in the study and not on other humeral nails with different design and identities.

Therefore, the term "humeral nailing" in a title, should not be used alone as, for example, the results of antegrade fixed-nailing may be different from results of retrograde bio-nailing for similar fractures. It is proposed that instead of saying or writing about "...plating V nailing..." or "...bracing V nailing..." we should be discussing "...plating V antegrade fixed-nailing..." or "...bracing V retrograde bio-nailing..." etc., Whenever a bio-nail is used in a study, location of the fracture should be clearly defined.

Humeral nailing tends to be considered a homogeneous surgical method. For that reason there are hardly any studies comparing different types of nails in the treatment of similar humeral fractures. Scheerlinck and Handelberg (2002) published a comparison study between the retrograde Marchetti-Vicenzi nail and the Unreamed AO Humeral Nail inserted with the antegrade technique. Although this is a study in the right direction, comparing a fixed-nail (UHN) with a bio-nail (Marchetti-Vicenzi), the criteria for nail selection to treat each fracture "...were based on..."
the surgeon’s preference and group consensus”. Nevertheless, the authors report that the retrograde Marchetti-Vicenzi nail was “preferably” used in more proximal fractures and the antegrade AO nail was used in more distal fractures, a statement that does not allow for reliable statistical comments. Furthermore, results from the use of the Marchetti-Vicenzi nail in proximal humeral fractures could be less satisfactory than if the same nail had been used in middle to distal humeral fractures (insertion from the short to the long segment), whilst with fixed-nailing the stability of the fracture site is less influenced by the insertion site.\textsuperscript{7,8,59}

Furthermore biomechanical studies in vitro, that compare intramedullary nails with different characteristics (and mechanical properties) (fixed-nails V bio-nails), appear biased and scientifically doubtful.\textsuperscript{32–34}

The stability offered by a fixed-nail is unquestionably superior to the stability offered by a bio-nail both in vivo and in vitro.\textsuperscript{32–34} However, what matters is the efficiency of an implant to offer a suitable environment for fracture healing in combination with low complication rates, low morbidity and rapid recovery parameters not examined in any of the biomechanical studies with cadaveric or plastic bones.\textsuperscript{52}

Summary

The expanding use of humeral nails and the development of new nail designs indicate that the future of humeral nailing in the treatment of humeral shaft fractures appears promising. Differentiating humeral from femoral and tibial nailing, along with creator understanding of the differences between types of humeral nails and insertion techniques will lead inevitably to better results. This will lead to expansion of the indications for the use of nails in the humerus. However, it seems that although humeral nailing is already challenging non-operative treatment there is still a long way to go to define its exact roles and indications in the treatment of humeral shaft fractures.

Practice Points

- Fixed-nails offer optimal stability and can be used for the osteosynthesis of any diaphyseal fracture. Although fixation from the short to the long segment has been recommended, both antegrade and retrograde techniques offer a good biomechani-

cal environment for prompt healing of any diaphyseal fracture. Drawbacks include the risks associated with the use of locking screws and occasionally difficult and time-consuming distal interlocking.
- Bio-nails offer less stability to the fracture site, which may be adequate for prompt union, something that remains to be defined and confirmed with future studies. Insertion from short to long segment is generally recommended; therefore an antegrade or retrograde technique should be dependent upon fracture location rather than preference of the surgeon. Drawbacks are the lack of absolute stability and problems related to each specific implant design. Advantages are the reduction of the risk of neurovascular problems and reduced operating time.
- Humeral nailing should be performed earlier rather than later, as the humerus is not a weight bearing bone. Reaming is generally not recommended in the humerus, especially during antegrade nailing.

Research Directions

- Clinical studies concerning humeral shaft fractures should be conducted by
  - defining—in the title—the type of implant used in the study,
  - comparing implants used for the fixation of similarly located fractures,
  - comparing different techniques in the fixation of similar fractures
- Biomechanical studies must compare implants with similar mechanical properties.

References

Humeral nails: When to choose what and how to use


63. Marchetti PG, Vicenzi G. Intramedullary fixation system, Surgical Technique Humerus. Edited by Zimmer.


