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Intramedullary nailing of the proximal humerus: evolution, technique, and results

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Proximal humerus fractures are the third most common fracture in the elderly. Although most fractures can be treated conservatively with acceptable outcomes, certain fracture patterns are at high risk for progression to humeral malunions, nonunions, stiffness, and post-traumatic arthrosis. The goal of antegrade humeral nailing of proximal humerus fractures is to provide stability to a reduced fracture that allows early motion to optimize patient outcomes. Certain technical pearls are pivotal in managing these difficult fractures with nails; these include rotator cuff management, respect of the soft tissues, anatomic tuberosity position, blood supply maintenance, knowledge of the deforming forces on the proximal humerus, fracture reduction, and rehabilitation strategies. Modern proximal humeral nail designs and techniques assist the surgeon in adhering to these principles and have demonstrated promising outcomes. Humeral nail designs have undergone significant innovation during the past 40 years and now can provide stable fixation in the humeral shaft distally as well as improved stability in the head and tuberosity fragments, which were the common site of fixation failure with earlier generation implants. Compared with other fixation strategies, such as locking plate fixation, no compelling evidence exists to suggest one technique over another. The purpose of this review is to describe the history, results, new designs, and techniques that make modern intramedullary nailing of proximal humerus fractures a viable treatment option.

Level of evidence: Narrative Review

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Proximal humerus fractures are the third most common fracture in the elderly. Whereas many fractures can be treated nonoperatively, some authors estimate that 15% to 64% of proximal humerus fractures are displaced and may warrant surgical treatment.[1] Conservative treatment of these fractures that results in humeral malunions, nonunions, stiffness, and post-traumatic arthrosis can be significantly disabling. In response, a variety of surgical techniques to treat these fractures have been developed, including plating, percutaneous pinning, suture or wire fixation, joint replacement, and humeral nailing. However, no single technique has demonstrated evidence-based superiority in the treatment of proximal humerus fractures.[18] In addition, several recent reports question the value of surgical treatment of these fractures as a

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whole[9,22] despite the widespread use of these various techniques.

Antegrade humeral nailing techniques and implants have undergone significant innovation during the last 40 years. The goal of nailing is to provide stability to a reduced fracture that allows early motion to rehabilitate the shoulder and to improve patient outcomes that may have otherwise been theoretically achieved with conservative management. Certain technical pearls are pivotal in managing these difficult fractures with nails; these include rotator cuff management, respect of the soft tissues, anatomic tuberosity position, blood supply maintenance, knowledge of the deforming forces on the proximal humerus, fracture reduction, and rehabilitation strategies. The purpose of this review is to describe the history, results, new designs, and techniques that make modern intramedullary nailing of proximal humerus fractures a viable treatment option.

History

"First-generation" nailing

The evolution of antegrade proximal humerus nailing began with the goal of achieving secure fixation of displaced proximal humerus fractures with a minimally invasive technique. The use of early intramedullary rods or nails, however, was not found to provide adequate fixation to neutralize the deforming forces in this type of fracture and often led to malunion or nonunion. The earliest intramedullary device attempted was Rush rod fixation. However, these pins were not sufficient to provide adequate fixation of displaced fragments and provided no rotational control. Proximal migration of the rod often led to acromial contact, requiring a second procedure for removal. The major issues with first-generation proximal humeral nails were the inability to secure unstable fracture fragments and lack of rotational control, often leading to fixation failure.

"Second-generation" nailing

To stabilize displaced fracture fragments better, antegrade proximal humerus nail designs evolved from experiences with locked lower extremity nails. Early proximal humeral locking nail designs included the Polarus nail (Acumed, Beaverton, OR, USA), the Telegraph nail (FH Orthopedics, Heimsbrunn, France), the Targon PH (Aesculap AG, Tuttlingen, Germany), and the Austofix PHN (North Plympton, SA, Australia). The original Polarus nail was an intramedullary locked, hollow, unreamed nail made of titanium alloy with specific features. These included a spiral array of locking screws, radiolucent targeting guide, axillary nerve window to avoid nerve injury, calibrated drills and drill guides, and cannulation to implant the rod percutaneously over a guidewire. Another unique feature of the Polarus nail was the proximal bend to allow easier lateral entry.

The major disadvantage of this generation of proximal humerus nails was inadequate security of the proximal interlocking screws. Although they were interlocking screws, they did not allow constructs that were fixed angular stable. As these screws engaged only the osteoporotic bone of the proximal humerus, fixation was often lost. Screw backout was common, requiring a secondary surgical procedure for removal.

"Third-generation" nailing

Third-generation nails evolved to solve the issue of proximal screw loosening and ultimate fixation failure. This led to the advent of more secure locking mechanisms for proximal screw fixation to allow fixed angular stable constructs (Table I). The Stryker T2 Proximal Humeral Nail (Stryker, Kalamazoo, MI, USA), for example, was designed to incorporate a number of features including a small diameter, left and right versions, end caps of different heights, and threaded proximal locking holes with a nylon bushing for improved holding strength. The Synthes Proximal Humeral Nail (Synthes, West Chester, PA, USA) offered a spiral blade for angular stable locking proximally, providing an increased surface area for fixation of the humeral head compared with screws with one plane of fixation. In this design, the proximal end cap was used to provide the angular stable locking mechanism for the blade. The Synthes MultiLoc Humeral Nailing System offers screw-in-screw technology for improved fixation in osteoporotic bone. The proximal locking screws target the posteromedial region with strong bone mineral density, potentially reducing the risk of varus collapse. The proximal ascending screw provides additional calcar fixation for medial support. The Tornier Aequalis Proximal Humeral Nail (Tornier, Bloomington, MN, USA) features a smaller core diameter with a shorter length to avoid engagement of the isthmus of the proximal humeral shaft, polyethylene bushings in the proximal holes to engage the proximal screws and to prevent screw backout, and more widely divergent proximal screws for "tuberosity-based" proximal fixation. Moreover, the nail is straight and was designed to be placed with a partial articular entry site.

Many features of the third generation of nail design address insertion and fixation. Modification of the proximal locking screws in some designs includes blunt screw tips to reduce the risk of secondary perforation, screw head suture holes to enable rotator cuff attachment, and countersunk screw heads to reduce acromial contact. The proximal bend in several offers insertion options laterally, just inside the greater tuberosity, or centrally, through the articular surface at the top of the humeral head. Central insertion improves fixation through interference between the subchondral bone at the entry point and the proximal end of the nail. Strategic proximal locking holes enable locking of the lesser tuberosity, the greater tuberosity, and the humeral head. Threaded proximal locking holes allow increased holding strength in the nail, analogous to locking plate and screw fixation. These angular stable

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