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ORIGINAL ARTICLE

Computed tomography–based prediction of the straight antegrade humeral nail's entry point and exposure of "critical types": truth or fiction?

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Background: Straight antegrade intramedullary nailing of proximal humerus fractures has shown promising clinical results. However, up to 36% of all humeri seem to be "critical types" in terms of the potential violation of the supraspinatus (SSP) tendon footprint by the nail's insertion zone. The aims of this study were to evaluate if a computed tomography (CT) scan could reliably predict the nail's entry point on the humeral head and if it would be possible to preoperatively estimate the individual risk of iatrogenic violation of the SSP tendon footprint by evaluating the uninjured contralateral humerus.
Methods: Twenty matched pairs of human cadaveric shoulders underwent CT scans, and the entry point for an antegrade nail as well as measurements regarding critical distances between the entry point and the rotator cuff were determined. Next, gross anatomic measurements of the same data were performed and compared. Furthermore, specimens were reviewed for critical types.
Results: Overall, 42.5% of all specimens were found to be critical types. The CT measurements exhibited excellent intra-rater and inter-rater reliability (intraclass correlation coefficients >0.90). Similarly, excellent agreement between the CT scan and gross anatomic measurements in contralateral shoulders (intraclass correlation coefficients >0.88) was found.
Conclusion: Assessing the uninjured contralateral side, CT can reliably predict the entry point in antegrade humeral nailing and preoperatively identify critical types of humeral heads at risk of iatrogenic implantation damage to the SSP tendon footprint. This study may help surgeons in the decision-making process

Institutional Review Board approval is not required because the use of anonymized cadaveric specimens is exempt at our institution.
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on which surgical technique should be used without putting the patient at risk for iatrogenic, implant-related damage to the rotator cuff.

Level of evidence: Anatomy Study; Imaging

Keywords: Proximal humerus fracture; fifth anchoring point; proximal anchoring point; straight antegrade humeral nailing; entry point; osteoporotic fracture

Fractures of the proximal humerus are the third most common fractures in patients older than 65 years.[1,12] Distinct treatment algorithms for displaced and unstable fractures remain controversial.[11,16] Various surgical techniques are available, ranging from minimally invasive K-wire or screw fixation, plating, and antegrade intramedullary nailing to hemiarthroplasty or reverse total shoulder arthroplasty. Evidence-based guidelines are still missing. Postoperative complication rates as high as 36% have been reported.[19,22] Varus dislocation, caused by comminution of the medial calcar, is a common failure mode.[13,24] The risks of failure increase exponentially in patients with osteoporosis.[13] In 3- and 4-part fractures, sufficient anchoring in the head fragment seems mandatory to provide stability. One possible solution to this problem is the creation of an additional proximal bony anchoring point provided by the tip of a straight antegrade humeral nail. Designated anchoring points within the humeral head are supplied by head locking screws. If all 4 head locking screw options are used, this additional anchoring point has been described as the "fifth anchoring point" for the MultiLoc nail (DePuy Synthes, West Chester, PA, USA).[21] The highest bone mineral density within the humeral head is located in the cranial, medial, and dorsal regions of the head. In contrast to the curvilinear nail, the tip of the straight nail is designed to anchor at the dense apex of the humerus and is therefore presumed to provide increased stability.[21] Furthermore, in 3-part fractures including a fracture of the greater tuberosity, the curvilinear nail may enter the humeral head within the fracture zone, whereas the straight nail's tip may potentially anchor the humeral head at the solid, not comminuted central and most proximal area. Clinically, straight intramedullary nails have been demonstrated to provide a union rate comparable to that of the curvilinear design, with a much lower incidence of complications.[15] However, because of anatomic variability, there is a risk of violation of the supraspinatus (SSP) tendon footprint even for straight nails, potentially additionally causing iatrogenic impairment of the patient's postoperative range of motion.[5] Diameters of straight nails available on the market range from 9.5 to 12.5 mm at the tip and 7 to 10 mm at the shaft, resulting in a recommended minimal proximal reaming diameter of at least 10 mm. This equates to 5 mm being the smallest possible radius needed for antegrade nailing procedures in the proximal humerus (critical distance [CD]) and 8 mm being the minimum safety distance from the critical point (CP) to avoid iatrogenic damage to the SSP tendon insertion while ensuring proper bone fixation.[5,8] Euler et al therefore defined the "safe type," not exceeding the safety distance, and the "critical type," exceeding the safety distance. They reported up to 36% of all humeri appearing to be critical types in terms of damaging the SSP tendon footprint by the nail's entry point.[5] They emphasized the need for "fastidious" preoperative planning to minimize the risk of iatrogenic violation of the rotator cuff. In order not to iatrogenically put the patient at risk, the individual anatomy may be assessed by using bilateral computed tomography (CT) scans of the shoulders to preoperatively scan for critical types.

However, it remains unclear if CT measurements do reliably reflect the macroscopic anatomy to sufficiently scan for the individual patient's qualification for straight antegrade humeral nailing procedures preoperatively. The aim of this study was to evaluate the feasibility of the individual anatomic prediction of the exact straight nail's entry point on the humeral head using CT scans of the contralateral side. We therefore hypothesized that CT scans are feasible to reliably predict the straight nail's entry point on the humeral head using the contralateral side. Clinically, this information is relevant to plan the surgical approach and furthermore to estimate the individual risk of potential iatrogenic violation of the SSP tendon footprint.

Materials and methods

Study design

Twenty matched pairs (10 male and 10 female) of osteoporotic cadaveric humeri were used for this study (n = 40 specimens). Specimens were chosen to be at least 70 years of age to be preferably osteoporotic, without any prior injuries or surgeries to their shoulders, and matched for gender. Median age was 81 years (range, 73-95); median body mass index was 22.4 (range, 15.4-34.7), and median bone mineral density was 70.8 mg/cm^3 (range, 51.6-88.4). CT scans of all specimens were conducted using an Aquilion Premium CT scanner (Toshiba America Medical Systems, Inc., Tustin, CA, USA). To assess measurement repeatability, all CT-based measurements were performed by 2 investigators. Two weeks after the initial round of measurements, 1 rater performed a second round of CT measurements. Meanwhile, gross anatomic measurements were conducted once and by a single rater. Scans were reconstructed 2-dimensionally in 3 perpendicular planes using IMPAX EE R20 (Agfa HealthCare N.V., Mortsel, Belgium). Using CT scans of paired and uninjured humeral heads, the ideal designated entry point on the humeral head for straight antegrade nailing, the CP (intersection between the sagittal axis of the most cranial extension of the greater tuberosity, the cortical border of the humerus in the anterior-posterior view), the