Morphologic evaluation of the ulna

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ABSTRACT **Intramedullary ulnar nailing may be technically difficult. We used various methods and measurements to determine the ideal nail entry point and the shape, length, diameter and curvature of the medullary canal in 44 human cadaver ulnas. We found that the ideal nail entry point was, on average, 7 mm proximal and 3 mm lateral to the most prominent area of the olecranon. A nail of 3 mm diameter could easily be inserted through a hole at the proximal-lateral side of the most prominent part of the olecranon, but only 20% of all nails could be easily inserted through a hole in the middle of the olecranon. We found that correct selection of a nail of proper length and diameter, as well as an ideal nail entry point on the olecranon are essential to successful nailing.**

Intramedullary forearm nailing is an alternative to plate fixation although this method is not without difficulties (Deluca et al. 1988, Zverev 1989, Zanasi et al. 1990, Boriani et al. 1991, Winckler et al. 1991, DePedro et al. 1992, Holmenschlager et al. 1995, Moerman et al. 1996, Holmenschlager et al. 1997, Labbe et al. 1998) . Correct nail length and diameter and the point of insertion depend on the anatomic structure of the ulna (Baranowski and Brug 1989, Boriani et al. 1991, Winckler et al. 1991, Zinar et al. 1996, Canale 1998). We determined the shape, length, diameter and curvature of the medullary canal in human dry cadaver ulnas to facilitate surgery.

Material and methods

We studied 44 adult ulna bones of undetermined age and gender. The donors were probably old people who had died of natural causes. The ulnas were numbered from 1 to 44. To elucidate the structure of the medulla along the bone and the relation between the cortex and medulla, 5 ulnas of the same length (nos. 8, 21, 24, 29, 32) were axially scanned at 3 cm intervals with CT, starting from the coronoid process in a distal direction (Figure 1). In addition, 1 ulna (no. 30) was cut with a saw from the coronoid process distally at 1 cm intervals and radiographs of all sections were taken (Figure 2).

Anteroposterior (AP) and mediolateral (ML) radiographs of each ulna were taken from a distance of 1 meter to determine the proper diameter of the nail to be used. Then, the thickest nails which could be driven into the distal end were inserted into the bones and another set of radiographs was taken. From the radiographs, the narrowest part of the ulnar medulla was determined, measured and compared to the diameter of the thickest nail which could be driven into the distal end of the bone.

We used round and straight intramedullary nails (Kirschner wires and Steinman pin) of various dimensions (lengths: 20, 22, 24, 26, 28 cm, diameters: 3, 3.5, 4, 4.5, 5 mm).

To determine the correct nail length, we used bone nos. 13, 26 and 34. The thickest nails which could reach to the distal end were inserted into the medulla. We measured the parts of the thickest nails inside the medullae, the lengths of the bones from the tip of the olecranon to the styloid process, and the mean length between the tip of an inserted nail and the styloid process (Figure 3, Table 2).

To find the best point for insertion of the nail, we inserted a nail of 3 mm diameter into 3 points on each olecranon: the center of the olecranon, 3 mm

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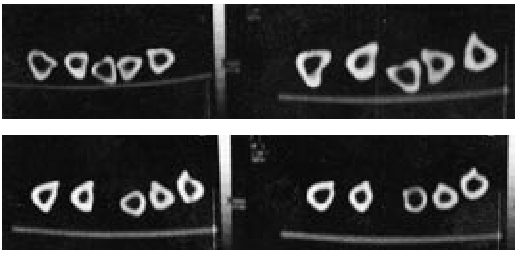

Figure 1. Ulna no. 21. Axial CT scan at 3 cm intervals.

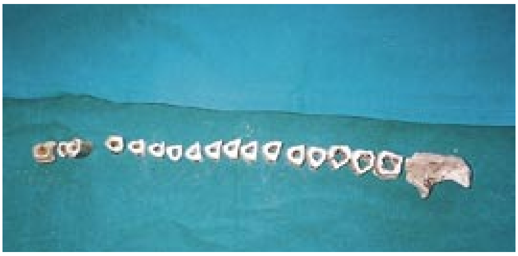

Figure 2. Ulna no. 30. Sections taken at 1 cm intervals and their x-ray images

Figure 3. Length determined between the tip of an inserted nail and the styloid process (l).

Table 1. The sides of the broken ulnas and where the retrogradely-inserted nails penetrated into the most prominent part of the olecranon

No.	Side	Lateral to most prominent (mm)	Proximal to most prominent (mm)
1	L	4	5
2	R	3	9
3	R	2	4
4	L	5	6
5	L	3	8
6	L	2	6
7	L	2	8
8	R	3	6

medial to the center, and 3 mm lateral to the center in 5 ulnas. The nails with a maximum diameter were inserted retrogradely through the medulla of 8 ulnas which had been broken distally at various lengths and pushed out of the olecranon. The positions of exit points were determined (Table 1).

In 5 randomly selected ulnas (1, 2, 3, 31 and 35), we opened 5 cm longitudinal windows along the bones to determine the points and areas on which the nail exerts stress. The anatomical sites of these windows on corresponding bones were as follows: no.1, posterior olecranon, no. 2, anterior border, no. 3, posterior border, no. 31, interosseous border, no. 35, from the point 5 cm distal to the tip of the olecranon posteriorly to the styloid process. While the nails were inside the medulla, we determined the contact points and areas.

Results

Anatomic and radiographic observations

Of the 44 ulnas studied, 26 were left. Their mean length was 25 (22–28) cm. 25 ulnas had a considerable radial deviation in the distal 1/5. In all ulnas, we observed medial and anterior deviations at the intersection of the medial and proximal 1/3 which indicated that the ulna has a lateral angulation at the proximal 1/3 (Table 2).

We found that the diameter and shapes of the medullae of the 5 ulnas differed on the axial CT scans taken at 3 cm intervals (Figure 1). The sections and radiographs of ulna no. 30 cut at 1 cm intervals showed that the diameter and shape of the medulla varied (Figure 2).

Table 2. The results in full length ulnas

No.	Side	Bone length (cm)	Nail length (cm)	Nail tip to styloid (mm)	Distal angulation	Narrowest area	Width on lateral radiographs	Width on AP radiographs
1	R	25	23	2	+	AP > Lat	Bone = Nail	Bone > Nail
2	L	22	20.5	1.5		AP = Lat	Bone > Nail	Bone > Nail
3	R	27	26	1	+	AP > Lat	Bone > Nail	Bone > Nail
4	L	25	21	4	+	AP = Lat	Bone = Nail	Bone > Nail
5	R	28	24	4	+	AP = Lat	Bone > Nail	Bone > Nail
6	L	25	20.5	4.5	+	AP > Lat	Bone > Nail	Bone = Nail
7	R	23	21	2		AP > Lat	Bone > Nail	Bone > Nail
8	R	24	23	1		Lat > AP	Bone > Nail	Bone > Nail
9	L	25	23.5	1.5	+	AP = Lat	Bone > Nail	Bone > Nail
10	R	27	23.5	3.5	+	AP > Lat	Bone > Nail	Bone > Nail
11	L	27	23	4	+	AP > Lat	Bone > Nail	Bone > Nail
12	L	26	23.5	2.5	+	AP > Lat	Bone > Nail	Bone > Nail
13	R	22	20	2		AP = Lat	Bone > Nail	Bone > Nail
14	L	26	23.5	2.5	+	AP = Lat	Bone = Nail	Bone = Nail
15	R	23	21.5	1.5	+	AP > Lat	Bone > Nail	Bone > Nail
16	R	25	20.5	4.5	+	AP > Lat	Bone > Nail	Bone > Nail
17	L	28	24	4		AP = Lat	Bone > Nail	Bone > Nail
18	L	23	20	3	+	Lat > AP	Bone > Nail	Bone > Nail
19	L	28	24.5	3.5	+	AP > Lat	Bone > Nail	Bone > Nail
20	R	27	25	2		AP = Lat	Bone > Nail	Bone > Nail
21	L	24	20	4	+	AP > Lat	Bone = Nail	Bone > Nail
22	L	24	22	2		Lat > AP	Bone > Nail	Bone > Nail
23	L	22	20	2.5	+	Lat > AP	Bone > Nail	Bone > Nail
24	L	24	21.5	1.5	+	AP > Lat	Bone > Nail	Bone > Nail
25	R	22	20.5	3	+	AP > Lat	Bone > Nail	Bone > Nail
26	R	26	23	2.5	+	Lat > AP	Bone = Nail	Bone = Nail
27	L	26	23.5	1.5		AP > Lat	Bone > Nail	Bone > Nail
28	R	25	23.5	1		AP = Lat	Bone > Nail	Bone > Nail
29	L	24	23	1	+	AP > Lat	Bone > Nail	Bone > Nail
30	R	26	24.5	1.5	+	AP > Lat	Bone > Nail	Bone > Nail
31	L	23	20	3	+	AP > Lat	Bone > Nail	Bone > Nail
32	L	24	20.5	3.5	+	AP > Lat	Bone > Nail	Bone > Nail
33	L	28	26	2		AP = Lat	Bone > Nail	Bone > Nail
34	R	25	22	3	+	Lat > AP	Bone > Nail	Bone > Nail
35	L	28	26.5	1.5		AP > Lat	Bone = Nail	Bone > Nail
36	R	22	21	1	+	AP > Lat	Bone > Nail	Bone > Nail

On the AP and ML radiographs, the diameters of the medullae at the narrowest segments were equal in 13 of the ulnas while the AP diameters were greater than the ML ones in 24% and the ML diameters were greater than the AP ones in 7.

Optimal entry point

The insertion through the medulla was easiest through the hole drilled in the proximal-lateral site of the olecranon with a nail of 3 mm diameter. Only 3/15 nails could be easily inserted through a hole in the middle of the olecranon. All of the thickest nails which could be driven through the medulla proximally penetrated the cortex and came out at the points lateral (2–5 mm, mean 3 mm) and proximal (4–9 mm, mean 6.5 mm) to the most prominent part of the olecranon.

Optimal nail diameter and length

The diameter of the narrowest part of the medullae and the diameter of the nail inserted were equal in 9, while the former was greater in 33 and the latter in 2. On the AP radiographs, the diameter of the narrowest part of the medulla was equal to the diameter of the nail in 3 bones and greater in the others. The smallest and largest diameters were 3 and 6 mm on the lateral radiographs versus 3.5 and 7 mm, respectively, on the AP radiographs. The mean distance between the tips of the nails inserted and the styloid process was 2.5 (1–4.5) cm.

Stress points in ulna

The stress points/areas for an intramedullary nail were posterolaterally in the olecranon, anteromedially in the proximal 1/3, posterolaterally in the middle 1/3 and posteromedially in the distal 1/3 of the bone.

Discussion

The ulna bows anterolaterally towards the radius in the proximal 1/3 and anteromedially in the distal 1/5, with the narrowest medulla in the middle 1/3 (the thickest cortical area), and the widest medulla in the distal 1/5 (the thinnest area) (Williams et al. 1989). McFarlane and MacDonald (1991) studied 142 adult ulnas with a mean length of 25 cm. They found that the medullary diameter was more than 4 mm in all 5 segments transversely cut from each bone. Zinar et al. (1996), on the other hand, reported a smallest diameter of 2–7 mm. We found it to be 3.5–7 mm on AP and 3–6 mm on ML radiographs. The AP measurements were equal to the ML ones in 1/3 of the bones.

There is no clear suggestion in the literature about which radiographic projections should be used to determine the correct diameter of the nail before surgery. It is obvious from the axial CT scans and from the direct radiograms of cut sections that the size and shape of the medullary canal of the ulna vary in different segments. Moreover, since the ulna has an anteromedial deviation in the proximal 1/3 and an anterolateral deviation in the distal 1/5 (Williams et al. 1989), it seems very difficult to choose a correct nail diameter.

The point of entry in the olecranon should be correctly selected, but its location is disputed. Zinar et al. (1996) defined it as follows: “The point of insertion in the ulna lies towards the radial side of the olecranon about 5 mm from the lateral cortex”. If one follows this recommendation, the trochlear articular surface of the olecranon will be injured in most cases. Canale (1998), on the other hand, stated that “The entry point should be in line with the center of the olecranon process and the center of the medullary canal”. However, we found that all of the nails with the largest diameters that were retrogradely inserted from the cut distal ends came out at a point proximal and lateral to the most prominent part of the olecranon (with an average of 6.5 mm proximal, 3 mm lateral). As the entry point was shifted towards the middle of the olecranon or more medially, even if the diameter of the nail was reduced, it was hardly possible to pass it through the medulla distally.

We found that it would be safer to decide the proper diameter of the nail by comparing the diameter of the thickest nail passed through the medulla to the diameter of the medulla at its narrowest part. On the lateral radiographs, the medulla, at its narrowest part, was 1 mm or more wider in half of the bones than the nail inside. The difference was between 0.5 and 1 mm in 1/5 of the bones. These findings suggest that preoperatively, the diameter of the nail to be used could be calculated by subtracting 1 mm from the diameter of the narrowest part measured on lateral radiographs taken from 1 meter. In currently available nail systems (Sage, Street, Cole, Tru-Flex, Fore Sight etc.), the diameters vary from 3 to 5 mm (Smith and Sage 1957, Street 1986, Zinar et al. 1996, Canale 1998). We suggest a nail system consisting of only 5 diameters: 3, 3.5, 4, 4.5, and 5 mm. This is because when a nail can not be inserted, a 0.5 mm smaller size can be easily used.

The present study showed that the length of the nail to be used can be calculated by subtracting 2.5 cm from the length of the ulna to be treated (the distance between the tip of the olecranon and the styloid process). If the radial deviation at the distal ulna is very marked, the correct length is found by subtracting as much as 4.5 cm. This will obviate damage to the medial cortex distally and prevent the nail from coming out from this end.

We also determined the stress points or angulation in the ulna. If an intramedullary nail causes stress during insertion, a nail of smaller diameter should be used.

Our study was performed on cadaver specimens from donors who were probably old. It may be that the diameter of the medullary cavity increases with increasing age. Therefore, we particularly recommend mediolateral radiographs for determining the diameter of the medullary canal.

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No competing interests declared.

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