Radioanatomical Measurements of the Medullary Cavity of the Humerus in Kuwait: Ethnic Differences and Clinical Implications for Fracture Fixation

Wieslaw Pospula Tarek Abu Al Noor Tarek Roshdy Ahmad Al Rowaih

Department of Orthopedics, Al-Razi Orthopedic Hospital, Kuwait

Key Words

Medullary cavity of the humerus · Radioanatomical study · Ethnic differences

Abstract

Objective: To compare the difference in diameter of the medullary cavity of the humerus in Arab and South Asian patients in Kuwait. **Subjects and Methods:** In 46 patients (29 Arab, 17 South Asian) treated at Al-Razi Hospital, Kuwait, for diaphyseal fracture of the humerus, the medullary cavity of the humerus on the radiographs of the uninjured (contralateral side) was examined. Bone density was also measured. Statistical significance was calculated by parametric and nonparametric test using SPSS package. **Results:** South Asians had a significantly narrower medullary cavity ($p < 0.05$) and higher cortical indices ($p < 0.05$) than Arabs, and also a narrower external diameter of the humerus at levels 5 and 6 ($p < 0.05$). **Conclusion:** In cases of fracture of the humerus, radiographic measurements of the diameter of the medullary cavity of the uninjured side were essential in selecting the appropriate fixation device.

Copyright © 2004 S. Karger AG, Basel

Introduction

Optimum treatment of diaphyseal fracture of the humerus remains a subject of debate. Although conservative and functional measures remain a recommended method of treating simple fractures [1], an increasing number of orthopedic centers prefer open reduction and internal fixation to avoid obvious disadvantages of nonsurgical treatment. Controversy also exists about whether intramedullary nailing or plating is the best surgical solution [2], since there are disadvantages to both methods, including excessive reaming and rotator cuff problems with nailing and loss of fixation, radial nerve palsy and infection with plate fixation [3].

In patients with a very narrow medullary cavity of the humerus, intramedullary nailing is extremely difficult using standard-sized hardware. In the belief that analysis of humeral anatomy may help in the selection of a more appropriate implant, we analyzed a series of radiographs of the contralateral humerus (unaffected by trauma) of Arab and South Asian patients treated for fracture of the humerus. Based on the radiograph measurements, the size of the medullary cavity of the humerus was determined with the goal of finding the most suitable fixation method.

KARGER

Fax +41 61 306 12 34
E-Mail karger@karger.ch
www.karger.com

© 2004 S. Karger AG, Basel
1011-7571/04/0134-0206\$21.00/0

Accessible online at:
www.karger.com/mpp

Wieslaw Pospula, MD, PhD
Al-Razi Orthopedic Hospital
PO Box 4235
13043 Safat (Kuwait)
Tel. +965 9862485, Fax +965 4842240, E-Mail pospulawieslaw@hotmail.com

Table 1. Length of the humerus, diameter of the humeral head, and diameter of the distal epiphysis in two ethnic groups

Measured parameter	Arabs	South Asians
Humeral length, mm	328.6 ± 23.8	319.1 ± 14.56
Diameter of the head, mm	50.8 ± 4.6	48.1 ± 5.3
Width of distal epiphysis, mm	62.4 ± 4.9	60.5 ± 5.6

Table 2. Diameter of the medullary cavity (MC) and external diameter of the humerus (HW) at different sites in the two ethnic groups

Measurement	Arabs	South Asians	p value
MC 1	25.6 ± 4.4	22.8 ± 4.3	<0.05
MC 2	15.4 ± 2.8	12.7 ± 2.8	<0.01
MC 3	12.2 ± 3.3	9.9 ± 1.8	<0.01
MC 4	10.6 ± 2.9	8.7 ± 1.6	<0.05
MC 5	9.5 ± 2.2	7.5 ± 1.1	<0.01
MC 6	9.1 ± 1.9	7.2 ± 1.3	<0.01
MC 7	11.0 ± 2.5	9.1 ± 2.4	<0.05
HW 1	30.6 ± 4.1	28.3 ± 4.4	>0.05
HW 2	23.2 ± 2.2	21.9 ± 2.1	>0.05
HW 3	22.8 ± 2.9	21.4 ± 2.3	>0.05
HW 4	21.4 ± 2.4	20.2 ± 2.1	>0.05
HW 5	20.3 ± 1.9	18.8 ± 2.4	<0.05
HW 6	19.8 ± 1.6	18.4 ± 2.3	<0.05
HW 7	25.1 ± 4.0	23.4 ± 4.9	>0.05

Subjects and Methods

In 46 patients operated on at Al-Razi Hospital, Kuwait, for diaphyseal fracture of the humerus, radiographs of the opposite, uninjured side were analyzed and different measurements were taken to identify characteristic features of the bone. Twenty-nine patients were of ethnic Arab origin and 17 were South Asian. Thirty-three of the patients were male and 13 female; the average age was 41.5 ± 11.3 years (19–65), and the average height, weight and body mass index (BMI) were 160.7 ± 9.8 cm (144–176 cm), 77.4 ± 14.8 kg (46–102 kg), and 30.3 ± 7.27 (20.4–49.2 kg), respectively. In 24 of the cases, the fracture of the humerus occurred on the right side, and in 22 cases on the left side. All patients except 4 were right-handed.

All radiographs were performed by the same radiographer maintaining a constant distance of 115 cm from the tube to the subject. On each radiograph a radiopaque ruler was projected to verify the magnification factor. Efforts were made to ascertain standard AP position in all radiographed patients. All measurements were done on the AP view by 2 independent observers using a precision ruler for longitudinal measurements and sliding caliper for transverse measurements, and the average of 2 measurements was recorded. Longitudinal measurements included the entire length of the humerus (HL), while transverse measurements entailed external humeral diameter (HW) and medullary cavity diameter (MC) in 7 constant locations

Fig. 1. Schematic presentation of the measured parameters.

that were arbitrarily selected (fig. 1). In addition, the width of the distal epiphysis (WDE) and the diameter of the humeral head (DH) were also measured. The sites of measurements were: third lumbar vertebra in AP view and hip in standard locations in the femoral neck, intertrochanteric zone and greater trochanter. All patients were subjected to standard densitometry using Hologic DEXA densitometer. Bone density was also determined at the upper humeral metaphysis and midshaft area of the humerus. Cortical index and BMI were calculated according to the following formulas. Cortical index was determined as $[(HW - MC)/HW] \times 100$, where HW is the width of the humerus and MC is the diameter of the medullary cavity. BMI was determined by the formula: $[weight/(height \times height)] \times 10,000$. Weight was given in kilograms and height in centimeters. Ethnicity was defined as either Arab or South Asian.

Statistical significance was determined by t test using SPSS program. Statistical calculations were done using independent samples t test.

Results

The longitudinal and transverse measurements for the two ethnic groups are depicted in tables 1 and 2. Cortical index and bone density measurements are presented in tables 3 and 4. The bone density of all patients fell within normal values and no significant differences were found

Table 3. Cortical index (CI) at different sites in ethnic groups

Measurement	Arabs	South Asians	p value
CI 1	16.7± 4.4	19.7± 4.3	<0.05
CI 2	33.9± 8.4	42.2± 8.4	<0.01
CI 3	46.8±10.8	53.7± 6.6	<0.05
CI 4	50.5±10.8	56.9± 6.4	<0.05
CI 5	53.1± 9.0	59.1± 8.6	<0.05
CI 6	54.1± 8.6	60.3± 9.2	<0.05
CI 7	55.6±10.1	60.6±10.1	<0.05

Table 4. Results of measurement of BMD in ethnic groups

Parameter	Arabs	South Asians
L3 AP, g/cm ²	0.991±0.150	1.017±0.150
FN, g/cm ²	0.838±0.104	0.880±0.149
GT, g/cm ²	0.689±0.124	0.753±0.132
IT, g/cm ²	1.156±0.195	1.199±0.159
DHU, g/cm ²	0.776±0.136	0.890±0.160
DHM, g/cm ²	1.121±0.202	1.300±0.198

L3 AP = Density at the level of the third lumbar vertebra; FN = density of the femoral neck; GT = density of the greater trochanter; IT = density of the intertrochanteric area; DHU = density of the humerus in the proximal segment; DHM = density of the humerus in the midshaft.

Table 5. Correlation between BMI and cortical index (CI) at different sites in the two ethnic groups (p < 0.001)

Measurement	Arabs	South Asians
BMI/CI 1	30.54/16.7	29.9/19.7
BMI/CI 2	30.54/33.9	29.9/42.2
BMI/CI 3	30.54/46.8	29.9/53.7
BMI/CI 4	30.54/50.5	29.9/56.9
BMI/CI 5	30.54/53.1	29.9/59.1
BMI/CI 6	30.54/54.1	29.9/60.3
BMI/CI 7	30.54/55.6	29.9/60.6

between the two ethnic groups (table 4). A significant positive correlation between the value of BMI, cortical index and bone mineral density (BMD) was found (tables 5, 6).

The diameter of the medullary cavity was significantly lower in South Asians than in Arabs at each measured level and with high significance (p < 0.01) at MC 2, MC 5 and MC 6 (fig. 2). The external diameter of the humerus

Table 6. Correlation between the BMI and BMD in the two ethnic groups (p < 0.001)

Measurement	Arabs	South Asians
BMI/L3 AP	30.54/0.991	29.9/1.017
BMI/FN	30.54/0.838	29.9/0.880
BMI/GT	30.54/0.689	29.9/0.753
BMI/IT	30.54/1.156	29.9/1.199
BMI/DHU	30.54/0.776	29.9/0.890
BMI/DHM	30.54/1.121	29.9/1.300

For abbreviations see table 4.

was also significantly narrower at HW 5 and HW 6. The values of the cortical index, however, were significantly higher in South Asians than in Arabs at each measured level, with p < 0.05 at CI 1, CI 3, CI 4, CI 5, CI 6, CI 7 and p < 0.01 at CI 2 level. In its narrowest site at the level of MC 6 the average diameter of the medullary cavity measured 7.5 mm (range from 5.1 to 9.8 mm) (tables 3, 4).

BMD was slightly higher in South Asians than in Arabs at all levels, but the differences were not statistically significant (p > 0.05) (table 4). BMI correlated positively with BMD in both ethnic groups (tables 5, 6) at all sites of measurement with high significance (p > 0.001).

There were no significant differences between the right or left sides in the measured parameters in both ethnic groups.

Discussion

There is a relatively small number of studies of humeral anatomy in the orthopedic literature, most of which focus on the design of shoulder prosthesis [4–6]. Recent interest in intramedullary unreamed nailing [7–9] has turned attention toward the medullary cavity using the magnetic resonance imaging technique [10]. In the absence of sophisticated equipment and computerized methods to directly measure bone dimensions [10–12], we measured the diameter of the medullary cavity and other parameters directly by precision ruler and sliding caliper. We believe that maintaining a standardized position for the patient during the radiograph and obtaining measurements by 2 independent observers can provide reliable data especially since minor rotational error was found to have a negligible effect on the results of measurements as previously reported [13]. The average magnifica-

Fig. 2. Comparison of two radiographs of patients with different ethnic origin. **a** Arabic patient. **b** Asian patient.

tion of all measured parameters was considered insignificant at 4%.

Just as other studies have indicated that ethnic differences may be reflected in skeletal variations [14], our study also showed variation in measurements of the medullary cavity, with a significant difference between Arabs and South Asian in all three parameters that characterize the medullary cavity (diameter, humeral width and cortical index).

The finding that the cortical index was significantly higher in South Asians than in Arabs at each measured level ($p < 0.05$ at several levels and $p < 0.01$ at CI 2 level) indicated that the cortical bone is thicker in South Asians than in Arabs for the entire length of the humerus, and the medullary cavity is more narrow as a result. The average measurement of the narrowest site of the medullary cavity in our patients (7.5 mm) is far lower than what was found by Murdoch et al. [10], where the diameter of the medul-

lary canal was estimated to be 12.1 ± 2.6 mm, without specifying the exact level.

As in the studies by Haapasalo et al. [15] and Alfredson et al. [16], in which measurements of the humeral bone mineral mass and cortical wall thickness in competitive sports players showed no significant differences between genders and sides, in our study there were likewise no significant differences in all measured parameters between males and females or between the right and left sides, in both ethnic groups. Studies by Leichter et al. [17] and Gilsanz et al. [18] also show no difference between genders. In our study there was a nearly equal number of right and left specimens (22 and 24, respectively), and handedness seemed not to influence these results as most of the patients were right-handed (91.3%).

The fact that BMI correlated positively with BMD in both ethnic groups at all sites of measurement with high significance ($p > 0.001$) is consistent with other studies conducted on series of patients of different ages and ethnicities. This finding reflects the general interrelation between BMI and mineral content of the skeleton, i.e. the higher BMI coincides with the higher BMD [19, 20]. In our study, BMD in the proximal and middle humerus had values higher than in the hip, especially in South Asians, contrary to a study by Doetsch et al. [21], which showed that the values of BMD in the shoulder area were lower than in the hip, reflecting the influence of the lack of weight bearing in the upper limb. These results, however, cannot be directly compared because of different ethnicities of the subjects involved in that study.

In our study, the cortical index also correlated positively with BMI: the higher the BMI, the higher the value of the cortical index in both ethnic groups. We can assume, therefore, that the cortical index coincides with BMD, but there are no available data in the bibliography for comparison. More detailed studies on more subjects may shed light on this problem.

Conclusion

Our study indicates that there are significant anatomical differences in the diameter of the medullary cavity of the humerus between the Arab and South Asian populations of Kuwait. This may have clinical relevance in the selection of the method of fixation in the surgical treatment of fracture of the humerus. In cases of very narrow medullary cavity, methods other than intramedullary nailing could be considered.

References

- 1 Sarmiento A, Latta LL: Functional fracture bracing. *J Am Acad Orthop Surg* 1999;7:66–75.
- 2 Modabber MR, Jupiter JB: Operative management of diaphyseal fractures of the humerus: Plate versus nail. *Clin Orthop* 1998;347:93–104.
- 3 Ochsner PE, Baumgart F, Kohler G: Heat-induced segmental necrosis after reaming of one humeral and two tibial fractures with a narrow medullary canal. *Injury* 1998;29(suppl 2):B1–B10.
- 4 Boileau P, Walch G: The three-dimensional geometry of the proximal humerus: Implications for surgical technique and prosthetic design. *J Bone Joint Surg* 1997;79B:857–865.
- 5 Pearl ML, Kurutz S: Geometric analysis of commonly used prosthetic systems for proximal humeral replacement. *J Bone Joint Surg* 1999;81A:660–671.
- 6 Pearl ML, Volk AG: Coronal plane geometry of the proximal humerus relevant to prosthetic arthroplasty. *J Shoulder Elbow Surg* 1996;5:320–326.
- 7 Brumback RJ: The rationales of interlocking nailing of the femur, tibia, and humerus. *Clin Orthop* 1996;324:292–320.
- 8 Watanabe RS: Intramedullary fixation of complicated fractures of the humeral shaft. *Clin Orthop* 1993;292:255–263.
- 9 Williams PR, Shewring D: Use of an elastic intramedullary nail in difficult humeral fractures. *Injury* 1998;29:661–670.
- 10 Murdoch AH, Mathias KJ, Smith FW: Measurement of the bony anatomy of the humerus using magnetic resonance imaging. *Proc Inst Mech Eng [H]* 2002;216:31–35.
- 11 Gualdi-Russo E, Russo P: A new technique for measurements on long bones: Development of a new instrument and techniques comparison. *Anthropol Anz* 1995;53:153–182.
- 12 Kunz C, Rieder T, Viehweger R: Can ultrasonography be used to measure torsion angle of the humerus? Comparison of ultrasonographic, computerized tomographic and anthropometric methods. *Z Orthop Ihre Grenzgeb* 1993;131:307–312.
- 13 Horsman A, Leung WK, Bentley HB, McLachlan MS: Effect of rotation on radiographic dimensions of the humerus and femur. *Br J Radiol* 1977;50:23–28.
- 14 Davis JW, Novotny R, Wasnich RD, Ross PD: Ethnic, anthropometric, and lifestyle associations with regional variations in peak bone mass. *Calcif Tissue Int* 1999;65:100–105.
- 15 Haapasalo H, Sievanen H, Kannus P, Heino A, Oja P, Vuori I: Dimensions and estimated mechanical characteristics of the humerus after long-term tennis loading. *J Bone Miner Res* 1996;11:864–872.
- 16 Alfredson H, Nordström P, Pietilä T, Lorentzon R: Long-term loading and regional bone mass of the arm in female volleyball players. *Calcif Tissue Int* 1998;62:303–308.
- 17 Leichter I, Weinreb A, Hazan G, Loewinger E, Robin GC, Steinberg R, Menczel J, Makin M: The effect of age and sex on bone density, bone mineral content and cortical index. *Clin Orthop* 1981;156:232–239.
- 18 Gilsanz V, Kovanlikaya A, Costin G, Roe TF, Sayre J, Kaufman F: Differential effect of gender on the sizes of the bones in the axial and appendicular skeletons. *J Clin Endocrinol Metab* 1997;82:1603–1607.
- 19 Munasinghe RL, Botea V, Edelson GW: Association among age, height, weight and body mass index with discordant regional bone mineral density. *J Clin Densitom* 2002;5:369–373.
- 20 Cetin A, Gokce-Kutsal Y, Celiker R: Predictors of bone mineral density in healthy males. *Rheumatol Int* 2001;21:85–88.
- 21 Doetsch AM, Faber J, Lynnerup N, Watjen I, Bliddal H, Danneskiold-Samsøe B: Bone mineral density measurement over the shoulder region. *Calcif Tissue Int* 2002;71:308–314.