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ORIGINAL ARTICLE

Is the pectoralis major tendon a reliable reference for restoration of humeral length with fracture hemiarthroplasty?

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Background: The primary objective was to calculate and to apply the numeric value of the distance from the pectoralis major tendon insertion to the superior aspect of the humeral head (PMTD) without any radiation exposure or equipment through basic data such as age, sex, height, and weight of Asian populations.
Methods: We analyzed shoulder magnetic resonance images of 260 patients (107 men and 153 women; average age, 59.8 years). The superior border of the pectoralis major was identified on the transverse section and cross-referenced with the coronal section. Measurements were made inferiorly from the corresponding transverse section to the top of the humeral head superiorly in coronal view. Correlation analysis was performed between variables including the patient's age, sex, height, weight, and body mass index and the PMTD by multiple linear regression analysis.
Results: The mean PMTD was 52 mm, with an average of 55 mm for men and 49 mm for women. Sex and height were significantly correlated with PMTD. The PMTD increased to a consistent level proportionally to height, and the difference in PMTD between men and women was 3.45 mm. An equation to estimate PMTD using these findings is as follows: PMTD (in mm) = 23 + (height [cm] × 0.17) + 3.45 (the last number is added for men). This equation had a prediction error of 0.3 mm.
Conclusion: Our study demonstrated that PMTD is a useful and reliable reference for optimal humeral height during hemiarthroplasty for proximal humerus fractures in Asian populations.
Level of evidence: Anatomy Study; Imaging

Keywords: Humeral fracture; pectoralis major; shoulder hemiarthroplasty; anatomic reference; magnetic resonance imaging; pectoralis major tendon; distance

Shoulder hemiarthroplasty is a recognized treatment for 4-part fractures, 3-part fractures with poor bone quality, fracture-dislocations, and large impaction fractures of the proximal humerus.[6,21-23,26,27] However, numerous studies have reported poor functional outcomes after hemiarthroplasty compared with satisfactory pain relief.[1,6,11,15,17,19,22,26,27,29] The key reason for poor functional outcomes is incorrect positioning of the prosthesis with subsequent loss of tuberosity

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reduction.[11,16,19,21,27] An important factor for accurate restoration of optimal humeral length in these complex fractures is proper placement and fixation of the tuberosities to the prosthesis.[12,14,20,22]

Various approaches to overcome this problem caused by loss of anatomic landmarks have been attempted. Preoperative templating with a full-length radiograph of the uninjured humerus has been suggested as a way to determine the height of the fracture stem.[4,5,9,18] However, it requires additional radiation exposure to the patient, which depends on the degree and variability of magnification, and interpretation may be difficult.[14,22,28] Some authors use the tension of the long head of the biceps as a reference; however, errors resulting in shortening or overlengthening of the humerus are not uncommon.[1,2,20] Others have suggested using specially designed jigs to reproduce predetermined humeral height, but these jigs can be too bulky to use and interfere with testing of the reattachment of the tuberosities.[3,28] Some authors prefer to calculate humeral lengthening during surgery on the basis of the medial diaphyseal calcar, but in cases of chronic fracture or severe comminution, this calculation may not be available or accurate.[2,6,7,20]

Several previous studies have reported a mean distance from the pectoralis major tendon insertion to the superior aspect of the humeral head (PMTD) of 56-57.73 mm[14,20,22,28] and supported the use of PMTD as a reliable guide in reconstruction of humeral length.[12,14,20,22,28] However, prior studies presented only simple measurements and did not provide formulas through detailed statistical analysis. In addition, these measurements were performed in Westerners, whose physique differs from that of most Asians. A predictable PMTD measurement as a patient's individual value is useful to determine reconstruction of humeral length in prosthetic replacement. We thought that it is important to obtain Asian values of the PMTD because of the recent increase in average life expectancy and the concomitant increase in unreconstructable osteoporotic fractures in Asian populations. Our goal was to calculate and to apply the numeric value without any radiation exposure or equipment through basic data such as age, sex, height, and weight of Asian populations.

In this study, we verified our hypothesis that the PMTD is a reliable reference to achieve optimal humeral height during hemiarthroplasty for proximal humeral fractures in Asian populations.

Methods

Magnetic resonance images of the shoulders of adult patients were procured from a consecutive cohort of 412 scans acquired with a 1.5T magnetic resonance imaging (MRI) system (Siemens Magnetom Avanto System; Siemens Medical, Erlangen, Germany). We cooperated closely with the department of radiology for precise measurements of this study; slice thickness of images was obtained as 3.6 mm when patients were undergoing MRI. We excluded 51 scans that showed an abnormal shape of the proximal humerus because of post-traumatic lesions or humeral head necrosis or any severe degenerative change, and an additional 101 scans were deemed not to have adequate imaging quality for confident measurements. Among the 260 patients whose shoulder images were selected, 107 were men and 153 were women; average age was 59.8 years (range, 18-84 years). Average height was 168.0 cm (range, 142.0-181.4 cm), average weight was 68.7 kg (range, 37.0-91.0 kg), and body mass index (BMI) was 24.3 (range, 15.0-32.9) (Table I).

Table I Demographic data of 260 shoulders (107 male, 153 female) used to determine distance from the pectoralis major tendon (PMTD) insertion to the superior aspect of the humeral head

	Mean	Range
Age (y)		
Overall	59.8	18-84
Male	71.8	18-76
Female	58.8	21-84
Height (cm)		
Overall	168.0	142.0-181.4
Male	170.5	142.0-168.0
Female	157.2	152.0-181.4
Weight (kg)		
Overall	68.7	37.0-91.0
Male	71.8	37.0-75.9
Female	58.8	45.0-91.0
Body mass index		
Overall	24.3	15.0-32.9
Male	24.7	18.0-29.8
Female	23.7	15.0-32.9
PMTD (mm)		
Overall	51.82	39.59-62.40
Male	55.21	47.19-62.40
Female	49.45	39.59-58.50

All examinations were read by 2 shoulder surgeons. The superior border of the pectoralis major tendon on the humerus was first identified on the transverse section and cross-referenced with the coronal section. On the coronal view, measurements were made inferiorly from the corresponding transverse section to the top point of the humeral head superiorly (Fig. 1).

SPSS Statistics (version 22.0; IBM, Armonk, NY, USA) was used for analysis and modeling of the data. Correlation analysis was performed between variables including the patient's age, sex, height, weight, and BMI and the PMTD, with a significance level set at P value of $< .05$. To increase the accuracy and statistical power, PMTD was measured 4 times, 2 times each by 2 shoulder surgeons independently, and the mean values were used for analyses. We used Cronbach α value to verify the reliability of the measurements; this value can be between 0 and 1, with higher values indicating higher reliability. Multiple linear regression analysis was performed with PMTD as a dependent variable. The independent variables were the patient's age, sex, height, weight, and BMI. We used a multiple stepwise regression model to find the most appropriate equation to explain the relationships and effects between PMTD and independent variables. Using the R^2 value, we determined the explanatory power of this model; the R^2 value is a measure of how well the linear regression equation