Scapular Notching Radiographic Analysis: Recommendations for Glenoid Plate Positioning and Glenosphere Overhang in Male and Female Patients

Introduction
An improved understanding of the relationship between prosthetic design parameters and patient-specific parameters is necessary to reduce the well-documented scapular notching rate associated with reverse shoulder prostheses. Recent work has recommended design modifications for manufacturers1 and surgical technique modifications for surgeons2 to improve range of motion (ROM) and stability and reduce scapular impingement. The purpose of this radiographic analysis of 226 patients who received one particular reverse shoulder design (Equinoxe; Exactech, Inc) and have been followed-up post-operatively for an average of 21.2 months is to correlate the position of the glenoid plate, the amount of glenosphere overhang, and the prosthetic-scapular neck angle to the clinical observation of notching. A statistical analysis of these radiographic measurements will yield recommendations for prosthesis placement for male and female patients in this study population to avoid notching.

Methods
Immediately post-op and the latest follow-up radiographs (21.2 ± 8.6 months) were collected from 226 patients (age = 72.9 ± 7.1 years; females = 155 and males = 71) who received a 38mm (n = 135), 42mm (n = 61), and 46mm (n = 10) Equinoxe reverse shoulder by 7 different surgeons at 7 different institutions. Each patient’s radiograph was scored for scapular notching by the implanting physician according to the Sirveaux grading scale. Placement of the glenoid plate peg from the inferior glenoid rim and the amount of glenosphere overhang was measured from each AP radiograph using digital calipers. Prosthesis-scapular neck angle was measured from each AP radiograph using a goniometer. Each radiographic measurement was compared to the scored notch position and glenosphere overhang for a subject. Two-tailed, unpaired t-test was used to identify differences in the radiographic measurements between patients with and without a notch, where p<0.05 denoted a significant difference.

Results
The radiographic analysis demonstrated that 22 of 226 patients had a scapular notch (16 Grade 1 and 6 Grade 2); no Grade 3 or 4 notches were observed. 115 females (38mm and 42mm glenospheres) were observed to have a scapular notching rate of 9.7%. Female patients (103.8 ± 38mm and 38 42mm glenospheres) were observed to have a scapular notching rate of 9.7% (13 Grade 1 and 2 Grade 2) whereas male patients (19 38mm, 42 42mm, and 10 46mm glenospheres) were observed to have a scapular notching rate of 9.9% (3 Grade 1 and 4 Grade 2). Patients with 38mm glenospheres were observed to have a scapular notching rate of 13.3% (13 Grade 1 and 5 Grade 2), patients with 42mm glenospheres were observed to have a scapular notching rate of 13.3% (3 Grade 1 and 1 Grade 2), and patients with 46mm glenospheres were observed to have a scapular notching rate of 0%. The average glenoid plate position for patients with a notch (19.1 ± 2.5mm) was significantly less (p = 0.037) than the average position for patients with a notch (20.1 ± 2.4mm). The average glenosphere overhang for patients without a notch (5.3 ± 2.5mm) was significantly more (p = 0.002) than the average overhang for patients with a notch (5.6 ± 2.4mm). The average prosthesis-scapular neck angle for patients without a notch (105.4 ± 14.6°) was not statistically different than the average angle for patients with a notch (105.8 ± 13.0°).

Regarding differences for females, the average glenoid plate position for female patients without a notch (18.5 ± 2.5mm) was significantly less (p = 0.026) than the average position for females with a notch (20.0 ± 1.8mm). The average glenosphere overhang for female patients without a notch (5.4 ± 2.5mm) was significantly more (p = 0.0025) than the average overhang for females with a notch (3.4 ± 1.6mm). The average prosthesis-scapular neck angle for female patients without a notch (105.6 ± 15.8°) was not statistically different than the average angle for females with a notch (106.3 ± 11.9°). Regarding differences for males, the average glenoid plate position for male patients without a notch (20.5 ± 4.9mm) was not significantly different than the average position for males with a notch (20.6 ± 3.7mm). The average glenosphere overhang for male patients without a notch (4.9 ± 2.7mm) was not significantly different than the average overhang for males with a notch (3.6 ± 3.9mm). The average prosthesis-scapular neck angle for male patients without a notch (105.0 ± 12.0°) was not statistically different than the average angle for males with a notch (106.7 ± 16.3°).

Comparing males and females, the average glenoid plate position for female patients without a notch was significantly less (p = 0.00003) than the average position for males without a notch. For 38mm and 42mm glenospheres, the average glenoid plate position for females was significantly less (p = 0.006 and 0.015, respectively) than the average position for males. Similarly, for 38mm and 42mm glenospheres, the average glenosphere overhang for females was significantly less (p = 0.001 and 0.009, respectively) than the average overhang for males.

Using the 95% confidence intervals on the average glenoid plate position and glenosphere overhang for male and female patients in this study population without a notch yields the following recommendations on placement of the glenoid plate and the minimum glenosphere overhang necessary to avoid scapular notching. For females, if the cage peg of the glenoid plate is placed at 18.1mm from the inferior glenoid rim it would reduce the female scapular notching rate from 9.7% to 1.9%. For males, if the cage peg of the glenoid plate is placed 19.5mm from the inferior glenoid rim it would reduce the male scapular notching rate from 9.9% to 1.4%. Similarly for females, a minimum glenosphere overhang of 5.9mm would reduce the female scapular notching rate from 9.7% to 0.7%. For males, a minimum glenosphere overhang of 5.6mm would reduce the male scapular notching rate from 9.9% to 2.8%.

Discussion and Conclusions
The results of this study demonstrate significant differences in both the glenoid plate position and glenosphere overhang between males and females and between patients with and without a notch. Gender differences result from differences in bone size, reflected by the larger percentage of males who received a 42 or 46mm glenosphere (73.2% vs 24.5% of females who received a 42 or 46mm glenosphere). Given this implant size distribution, this study identifies differences and make recommendations for optimal implant placement in order to reduce notching in males and females. These recommendations are specific to the Equinoxe reverse shoulder; care should be made when extrapolating these results to other reverse shoulder devices due to differences in design parameters. Additionally, there is a functional limit to how much glenosphere overhang is achievable; implant positioning should take a particular patient’s soft tissue laxity into account. The primary limitation of this study is the degree that the study population represents the global reverse shoulder patient population; this concern is mitigated by the large sample size (n=226) and wide distribution of surgery sites (7 institutions: 3 teaching and 4 private hospitals; 2 different countries).

Significance
Scapular notching is the most common complication of reverse shoulder arthroplasty. This large scale radiographic evaluation quantifies implant position in males and females and makes surgical technique recommendations to reduce the scapular notching complication rate.

References