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# Infraspinatus and deltoid length and patient height: implications for lateralization and distalization in reverse total shoulder arthroplasty

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**Background:** Restoration of muscular strength is predicated on restoration of muscle length. The purpose of this study was to describe infraspinatus and deltoid length preoperative to reverse total shoulder arthroplasty (RTSA) to guide distalization and lateralization to restore preoperative muscle length.

**Methods:** This was a retrospective radiographic study. We measured the infraspinatus length on preoperative computed tomographic images and the deltoid length on preoperative radiographs. For all measurements, reliability was first established by comparing measurements between 2 observers, and intraclass correlation coefficients (ICCs) were calculated. We then calculated descriptive statistics for these muscle lengths and developed a formula to predict these muscle lengths from patient demographics.

**Results:** We measured infraspinatus length in 97 patients and deltoid length in 108 patients. Inter-rater reliability was excellent, with all ICCs >0.886. The mean infraspinatus length was 15.5 cm (standard deviation 1.3) and ranged from 12.6-18.9 cm, whereas the deltoid length was 16.2±1.7 cm and ranged from 12.5-20.2 cm. Both infraspinatus ($r = 0.775$, $P < .001$) and deltoid length ($r = 0.717$, $P < .001$) were highly correlated with patient height but did not differ between diagnoses. Formulae developed through linear regression allowed prediction of muscle length to within 1 cm in 78% and within 2 cm in 100% for the infraspinatus and 60% and 88% for the deltoid.

**Conclusion:** Deltoid and infraspinatus length are variable but highly correlated with patient height. To maintain tension, 2 mm of lateralization and distalization should be added for every 6 inches (∼15 cm) of height above average for a Grammont-style RTSA.

**Level of evidence:** Anatomy Study; Imaging



**Keywords:** Reverse total shoulder arthroplasty; shoulder arthroplasty; shoulder anatomy; infraspinatus; deltoid; shoulder

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Reverse total shoulder arthroplasty (RTSA) has excellent long-term outcomes.[2,3,11] However, the optimal implant design remains controversial, with significant variation in both lateralization and distalization between surgical techniques and between implant systems.[6,12,16,20,31] These factors vary postoperatively by 5-6 cm between patients[23]

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and by 2 cm between implant systems.[31] Lateralization variation alters tension within the infraspinatus and distalization variation alters tension within the deltoid. Variation in tension alters muscular function.[8]

Historically, there have been several studies to describe normal muscle length in the deltoid and infraspinatus.[1,4,19,22,26,29,33] Numerous computed modeling studies have been conducted using previously described normal lengths.[5,9,28,32] However, many patients who undergo RTSA have medialization and proximalization of the humerus associated with glenohumeral osteoarthritis or rotator cuff tear arthropathy. These lead to chronic shortening of the infraspinatus and deltoid, respectively. It remains unclear whether the findings of the prior anatomic studies translate to the pre-RTSA clinical situation. Furthermore, muscle length differs between patients depending on overall body habitus.[10,15,21,34] No formulae are currently available to allow the surgeon to predict infraspinatus or deltoid length based on patient height.

As of this writing, multiple software suites are available that allow preoperative planning prior to shoulder arthroplasty.[8,13] These software suites use computed tomography (CT) data to create 3-dimensional osseous models and allow the surgeon to preoperatively plan implant position relative to the 3-dimensional osseous anatomy. However, these models do not include or account for soft tissues and thus provide no guidance as to muscular tensioning. It is not straightforward for the surgeon to measure infraspinatus or deltoid length by hand preoperatively, as in both magnetic resonance imaging and CT scans these muscles are not fully contained within a single slice and are often not completely contained within the field of view. Thus, with the present technology, it is not straightforward or easy for the surgeon to measure infraspinatus or deltoid length preoperatively.

Without knowledge of infraspinatus and deltoid length, the surgeon is left only with the intraoperative ‘‘feel’’ of muscular tension during implant trialing. If infraspinatus and deltoid length could be accurately predicted, then the surgeon would have a framework to guide interpatient variation in implant sizing to create equivalent tension between patients across variations in infraspinatus and deltoid length. Such formulae would allow the patient with a ‘‘short’’ infraspinatus or deltoid and the patient with a ‘‘long’’ infraspinatus or deltoid to achieve equivalent tensioning by guiding the surgeon as to how to alter implant size between these 2 patient sizes to achieve equivalent tensioning. Development of a predictive model for infraspinatus and deltoid length thus has implications for RTSA sizing. Development of a predictive model infraspinatus and deltoid length is thus a critical knowledge gap in RTSA preoperative planning. Thus, the purpose of this study was to describe infraspinatus and deltoid length to guide distalization and lateralization to restore preoperative muscle length. We hypothesized that infraspinatus and deltoid length would be highly variable but would correlate with patient height

## Methods

### Patient selection

This is a retrospective comparative radiographic study. After initial feasibility analyses, we determined that most preoperative anteroposterior Grashey radiographs at the first author’s university did not extend to the deltoid tuberosity, and that most of the patients at our collaborator’s university did not have preoperative CT scans. Thus, we selected a multicenter approach for this study in which we measured infraspinatus length from preoperative CT scans from the first author’s university (University of Utah) while we measured deltoid length from preoperative anteroposterior Grashey radiographs from our collaborator’s university (Washington University in St Louis). At the leading author’s institution, we reviewed all patients who underwent RTSA by the authors between January 1, 2007, and January 1, 2020. We only included those patients who had a preoperative CT scan, no history of humeral or scapular fracture, no prior metallic implants, and a diagnosis of either glenohumeral osteoarthritis or the sequelae of rotator cuff disease. To ensure that pathology of the rotator cuff will not disrupt measurements of deltoid or infraspinatus length, we included both glenohumeral osteoarthritis and the sequelae of rotator cuff disease and we compared the two. At our collaborator’s institution, we reviewed all patients who underwent RTSA by the author between January 1, 2019, and January 1, 2020. We only included those patients who had an adequate-quality preoperative Grashey radiograph including the deltoid tuberosity, no history of humeral or scapular fracture, no prior arthroplasty, and a diagnosis of either glenohumeral osteoarthritis or the sequelae of rotator cuff disease.

### Data collection

Via chart review, we collected the following information: gender, age at time of imaging, and height. We also reviewed each operative report, and based on the described findings we categorized the diagnosis for patient as the sequelae of rotator cuff tears or glenohumeral osteoarthritis.

### Measurement technique

#### Infraspinatus length

On 3-dimensional CT imaging, we made the following measurements in a third-party viewer (OsiriX; Pixmeo Sarl, Bern, Switzerland). First, the software autosegmented the osseous anatomy, and we made all measurements on 3D reconstructions of scapula and humerus. From a posterior viewing angle, we measured the distance between the medial border of the scapula and the lateral aspect of the greater tuberosity at the superior

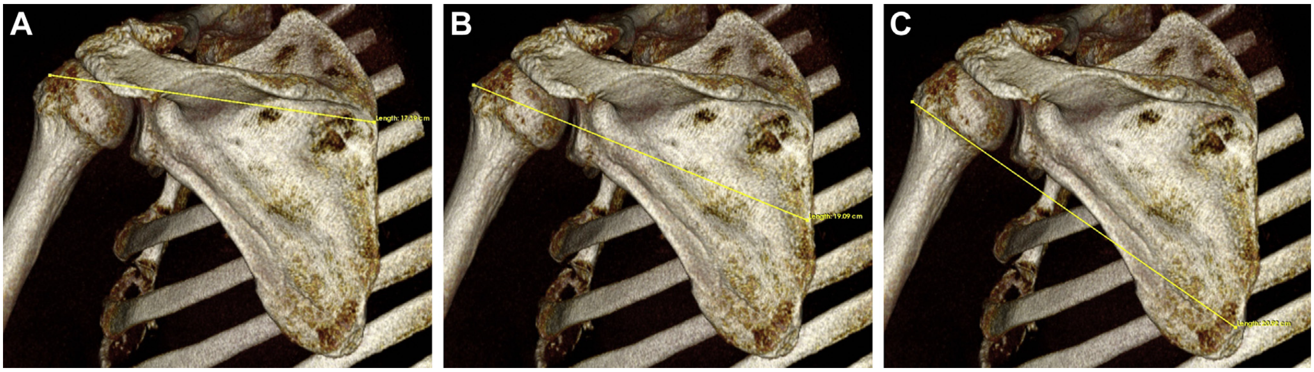


**Figure 1** A 3-dimensional reconstruction of a computed tomographic scan of the shoulder, viewed posteriorly, demonstrating the measurement technique for the (**A**) upper (**B**), mid-, and (**C**) lower infraspinatus.

aspect of the infraspinatus fossa just below the scapular spine, at the inferior aspect of the infraspinatus fossa just above the thickening of the inferior angle, and at the midpoint between these 2 aspects (Fig. 1). Two observers blinded to each other's measurements made these measurements in triplicate. We made measurements of osseous landmarks instead of measurements of the actual soft tissue muscle-tendon unit both because it was felt that osseous landmarks could be more accurately and reliably identified on CT scans than soft tissue landmarks and also so that measurements could be made on autosegmented 3D reconstructions, instead of 2D slices, to better capture the 3-dimensional shape of the muscle.

### Deltoid

On a 2-dimensional anteroposterior Grashey radiograph, we made the following measurements in a third-party viewer (OsiriX; Pixmeo Sarl). We measured the distance between the lateral aspect of the acromion and the middle of the deltoid tuberosity (Fig. 2). We have previously demonstrated that within radiographs of this type taken at this university there are negligible magnification effects.[7] Two observers blinded to each other's measurements made these measurements.

## Statistical methods

We calculated and reported descriptive statistics. We performed all analyses in Excel X (Microsoft, Redmond, WA, USA) and SPSS 25 (IBM, Armonk, NY, USA). To determine the association between diagnosis and infraspinatus and deltoid length, we performed Student *t* tests or Mann-Whitney *U* tests as appropriate depending on data normality as determined using the Kolmogorov-Smirnov test. To determine the association between patient age and height and infraspinatus and deltoid length, we performed Pearson or Spearman correlation coefficients, as appropriate depending on data normality as determined using the Kolmogorov-Smirnov test. We conducted linear regression using those variables found to be significantly different on the univariate analysis. As this was a retrospective study, we used all available patients and no a priori power analysis was conducted. We considered $P$ values of $<.05$ statistically significant.

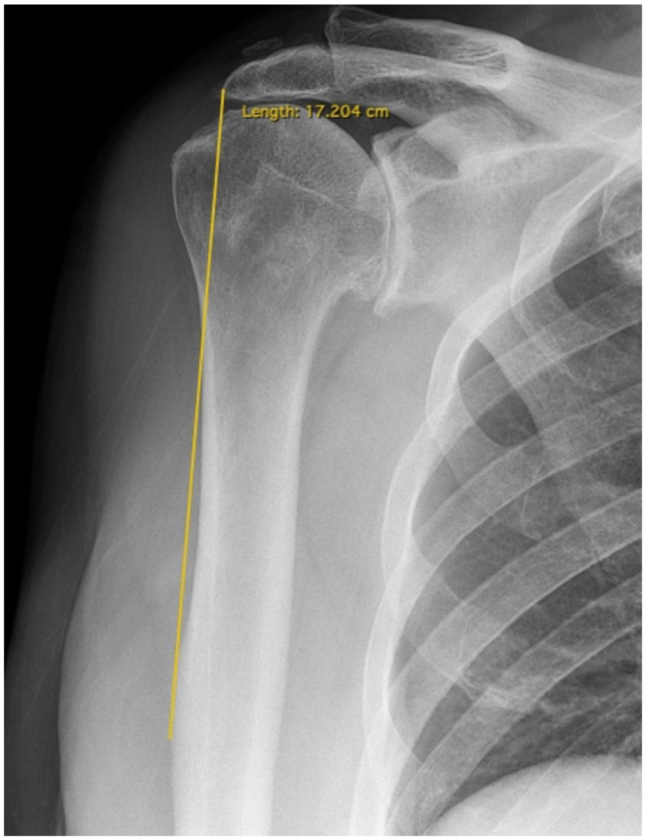


**Figure 2** An anteroposterior Grashey radiograph demonstrating the measurement technique for deltoid length.

## Results

### Included patients and reliability

#### Infraspinatus

During the study period, 160 patients underwent an RTSA and had a preoperative CT scan. Of these, 62 were excluded because there was a prior metallic implant or fracture and 1 was excluded because his height had not been documented, leaving 97 patients who were included within our study. These patients were 62% female (60/97) with a mean ± standard deviation (range) age of 71±10 years (45-93) and height of 167±11 cm (145-193). Of these RTSAs, 44% (43/97) were performed for glenohumeral osteoarthritis and 56% (54/97) were performed for rotator cuff tear arthropathy. When examining measurement reliability, it was also found to be excellent, with all ICCs >0.890 (Table I).

### Deltoid

During the study period, 149 patients underwent RTSA as a primary arthroplasty. Of these, 5 were excluded because of preoperative fracture, 29 were excluded because the preoperative anteroposterior Grashey radiograph was of insufficient length to see the deltoid tuberosity, 5 were excluded because the preoperative anteroposterior Grashey was of insufficient quality to judge deltoid length or was missing, and 2 were excluded for diagnoses other than glenohumeral osteoarthritis or rotator cuff tear, leaving 108 patients whom we included within our study. These patients were 53% female (57/108) with a mean ± standard deviation (range) age of 70±7 years (38-86) and height of 170±12 cm (145-196). Of these RTSAs 57% (62/108) were performed for glenohumeral osteoarthritis and 43% (46/108) were performed for the sequelae of a rotator cuff tear tear. When examining measurement reliability, it was also found to be excellent, with an ICC of 0.892 (Table I).

## Infraspinatus length

Infraspinatus length was an average of 3 cm longer for the lower infraspinatus as compared to the upper infraspinatus (Table II). There were no significant differences in infraspinatus length between patients with rotator cuff tear arthropathy (15.6±1.3 cm) and patients with glenohumeral osteoarthritis (15.6±1.3 cm, $P = .858$). There was no significant correlation between age and infraspinatus length ($r = -0.203$, $P = .065$) but there was a significant correlation between height and infraspinatus length ($r = 0.775$, $P < .001$). In our linear regression model, patient height was a significant predictor of infraspinatus length ($P < .001$, $r^2 = 0.601$). Linear regression was optimized using the formula:

**Table I** Accuracy and reliability statistics for each of the included variables

| Variable | ICC (95% CI) |
|---|---|
| Lower infraspinatus | 0.963 (0.913-0.981) |
| Mid infraspinatus | 0.969 (0.952-0.979) |
| Upper infraspinatus | 0.890 (0.834-0.926) |
| Deltoid | 0.892 (0.843-0.925) |

*ICC*, intraclass correlation coefficient; *CI*, confidence interval.

**Table II** Infraspinatus length

| Variable | Mean ± standard deviation (range) (cm) |
|---|---|
| Lower | 17.2 ± 1.5 (14.4-20.6) |
| Middle | 15.5 ± 1.4 (12.6-19.0) |
| Upper | 13.9 ± 1.3 (10.9-18.0) |
| Overall | 15.5 ± 1.3 (12.6-18.9) |
| Predicted | 15.6 ± 1.0 (13.6-18.0) |
| Measured vs. predicted | 0.6 ± 0.5 (0.0-2.9) |

$$\text{Infraspinatus length (cm)} = 0.456 + 0.091 \times \text{(patient height in cm)}$$

Using this formula, the difference between the measured and the predicted infraspinatus length was 0.6±0.5 cm. In 51% (49/97) of cases, the difference between predicted and measured was <0.5 cm; in 78% (76/97) of cases, the difference between predicted and measured was <1 cm; and in 100% of cases, the difference between predicted and measured was <2 cm.

## Deltoid length

The mean deltoid length was 16.2±1.7 cm (12.5-20.2). There were no significant differences in deltoid length between patients with the sequelae of a rotator cuff tear (16.1 ± 1.9 cm) and patients with glenohumeral osteoarthritis (16.4 ± 1.5 cm, $P = .286$). There were significant correlations between age and deltoid length ($r = -0.216$, $P = .025$) and height and deltoid length ($r = 0.717$, $P < .001$). In a stepwise linear regression model, patient height was the only significant predictor of deltoid length ($P < .001$, $r^2 = 0.514$). Linear regression was optimized using the formula:

$$\text{Deltoid length (cm)} = -1.965 + 0.107 \times \text{(patient height in cm)}$$

Using this formula, the difference between the measured and the predicted deltoid length was 1.0±0.7 cm. In 26% (29/108) of cases, the difference between predicted and measured was <0.5 cm; in 60% (65/108) of cases, the difference between predicted and measured was <1 cm; and in 88% (95/108) of cases, the difference between predicted and measured was <2 cm.

## Discussion

Within our study, infraspinatus length was highly variable, varying over a range of 5 cm. However, it could be predicted within a centimeter in 78% of cases based on patient height alone. Deltoid length was also found to be highly variable, varying over a range of 7.5 cm. However, it could also be predicted to within a centimeter in 60% of cases based on patient height alone. These height–muscle length relationships allow surgeons to make more anatomically driven choices regarding distalization and lateralization between patients based on known patient characteristics.

Our infraspinatus lengths are very similar to prior studies. In a study of 12 normal cadavers, infraspinatus length was 13.2±1.8 cm superiorly, 16.2±1.7 cm centrally, and 17.7±1.9 cm inferiorly.[1] Similarly, in another study of 10 cadavers, infraspinatus length was 13.2±1.7 cm superiorly and 16.0±2.4 cm in the midinferior region, and 16.7±2.6 cm inferiorly.[19] However, within this same study there was significant variation: for instance, within the superior portion of the infraspinatus, length varied from 9.3-15.4 cm.[19] Another study described a similar 5-cm variation in infraspinatus length between cadavers.[4] This 5-6-cm variation in native infraspinatus length must then be understood within the context of 7-mm changes in humeral offset between implant designs[18] or 1.3-cm differences in center of rotation lateralization between prosthesis designs, as detailed below.[25] Thus, the 19.5-mm medialization provided by a traditional Grammont design RTSA creates ∼12% shortening within the infraspinatus, whereas the 6.4-mm medialization provided by a lateralized-design RTSA creates 4% shortening within the infraspinatus.[25] Prior laboratory data do suggest that as long as sarcomere length is within 15% of the ideal in muscle length–tension relationship, there is preservation of 90% muscle strength.[13,27] The optimal center of rotation between medialized/distalized Grammont-style and lateralized/non-distalized Frankle-style RTSA remains controversial, with both demonstrated to have good long-term outcomes.[2,11,17] Our results do not allow conclusions regarding the superiority of one implant compared with the other.

Our infraspinatus length data allow the surgeon to make more anatomically driven choices between glenosphere options. For instance, the average patient is very close to 168 cm (5 feet 6 inches) with an infraspinatus that is predicted to be 15.7 cm, and a patient who is 6 feet tall (183 cm) is predicted to have an infraspinatus that is 17.1 cm; that is, 9% longer than the infraspinatus of a patient who is 5 feet 6 inches tall. Let us assume that the surgeon has decided that a 38-mm glenosphere is appropriate for the average patient in his or her experience. This glenosphere provides 19 mm of lateral offset between the glenoid face and the articular surface (38/2). To increase this lateral offset 9%, an additional 1.6 mm of lateralization (ie, a +2 glenosphere) is needed. Thus, a 38-mm glenosphere in a 5 feet 6 inches tall individual will achieve the same infraspinatus tensioning as a 40-mm glenosphere in an individual who is 6 feet tall. We have calculated several similar scenarios to provide surgeons with a guide as to how to alter their lateralization based on patient height. This guide can be used for the most common sizes of glenospheres (Table III). As a general rule of thumb, these numbers suggest ∼2 mm of glenosphere lateralization for every 6 inches (∼15 cm) of height above average for non-lateralized/distalized Grammont-style glenospheres and vice versa. However, certainly these serve only as guidelines and cannot substitute for preoperative planning of implant position and intraoperative assessment of stability and tension.

Our described deltoid lengths are also similar to prior studies, demonstrating substantial variation in deltoid length from 12.5-20 cm. In a study of 11 cadavers, anterior deltoid length was 14.4±0.8 cm, middle deltoid length was 16.1±0.6 cm and posterior deltoid length was 17.8±0.6 cm.[22] Another cadaver study found that deltoid length varied from 19-23 cm.[4] A prior computed modeling study suggested that 10% elongation of the deltoid would maximize deltoid moment arms in RTSA, which equates to ∼1.6 cm. Interestingly, a prior retrospective RTSA study found mean lengthening in 60 patients post-RTSA to be 20.4 mm.[24] A prior retrospective comparative study of 56 patients found deltoid lengthening of 1.0-2.5 cm to be associated with the highest Constant scores.[30] A retrospective analysis performed at our own institution (unpublished data) demonstrated a mean of 29 mm of distalization in 230 patients. Overall, these prior results suggest that 15-30 mm of distalization may be average for a distalized, Grammont-style RTSA. Within the mean deltoid length of 16.2 cm, 15-30 mm of distalization equates to 9%-19% deltoid lengthening. Again, prior laboratory data suggest sarcomere lengths within 15% of the ideal in muscle length–tension relationship allow preservation of 90% muscle strength.[13,27]

Our deltoid length data allow reinterpretation of these prior distalization measures. However, these numbers must be considered in light of the significant variation in deltoid length, from 12.5-20 cm within our data set. For instance, the average patient (height of 5 feet 6 inches, or 168 cm) has a deltoid that is 16.2 cm in length, and a patient who is 6 feet tall (183 cm) is predicted to have a deltoid that is 17.6 cm in length, that is, 9% longer than the deltoid of a patient who is 5 feet 6 inches. Let us assume that the surgeon is using a medialized and distalized Grammont-style RTSA, which typically distalizes 2 cm and has decided that deltoid tensioning is appropriate for the average patient in his or her experience. To increase the distalization 9%, an additional 2.0 mm of distalization (ie, a +2 polyethylene) is needed. Thus, assuming implant positioning and glenosphere choice to be constant, a +2 polyethylene in a 6-foot-tall individual will achieve the same deltoid tensioning as a 0 polyethylene in an individual who is 5 feet 6 inches tall. We have calculated several similar scenarios to provide surgeons with a guide as to how to alter their distalization based on patient height (Table IV). As a general rule of thumb, it is typical for a distalized/nonlateralized Grammont-style RTSA to distalize 20 mm,[24,30] and the corresponding column of Table IV suggests ∼2 mm of

**Table III** Suggested lateralization changes for varying glenosphere sizes to result in the same effect on final infraspinatus length based on predicted infraspinatus length for a range of patient heights

| Patient height | Predicted infraspinatus length (cm) | Additional lateralization (+) or medialization (–) (in mm) for each glenosphere size (in mm) and style | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Nonlateralized Grammont-style | | | | Lateralized Frankle-style | | | | |
| | | 36 | 38 | 40 | 42 | 36-4/40-4 | 32-4 | 36/40 | 32 | 44 |
| 4′6″ (137 cm) | 12.9 | −3.2 | −3.4 | −3.6 | −3.8 | −3.6 | −3.9 | −4.3 | −4.6 | −5.4 |
| 4′9″(145 cm) | 13.7 | −2.4 | −2.5 | −2.7 | −2.8 | −2.7 | −2.8 | −3.1 | −3.3 | −3.8 |
| 5′0″ (152 cm) | 14.3 | −1.7 | −1.8 | −1.8 | −1.9 | −1.8 | −2.0 | −2.1 | −2.3 | −2.7 |
| 5′3″ (160 cm) | 15.0 | −0.8 | −0.9 | −0.9 | −1 | −0.9 | −1.0 | −1.1 | −1.2 | −1.3 |
| 5′6″ (168 cm) | 15.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5′9″ (175 cm) | 16.4 | 0.7 | 0.8 | 0.8 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 |
| 6′0″ (183 cm) | 17.1 | 1.6 | 1.6 | 1.7 | 1.8 | 1.7 | 2.0 | 2.1 | 2.3 | 2.7 |
| 6′3″ (191 cm) | 17.8 | 2.4 | 2.5 | 2.7 | 2.8 | 2.7 | 2.9 | 3.2 | 3.5 | 4.0 |
| 6′6″ (198 cm) | 18.5 | 3.1 | 3.3 | 3.5 | 3.6 | 3.5 | 3.9 | 4.3 | 4.6 | 5.4 |

To use this table, the surgeon should first decide which glenosphere they feel best fits the "average" (i.e. 5′6″) patient for their surgical technique and operative experience. This glenosphere then provides the column that this surgeon should use to make decisions. Pre-operatively, they should examine the height of the pre-RTSA patient, then use the row for this height to adjust additional lateralization/medialization for that patient. For instance, one of the senior authors most commonly (>90% of cases) uses a 36 mm glenosphere in a medialized Grammont-style system, suggesting that this glenosphere best fits the average patient for this surgeon. This surgeon would then use the 36 mm Grammont-style glenosphere column to decide how much to lateralize or medialize to achieve the same tension across variation in patient height (and infraspinatus length). Thus, for this surgeon, consideration should be given to adding a +2 lateralized glenosphere (or upsizing to a 40 mm glenosphere) for patients over 6′0″ and to reaming an extra 2 mm for patients under 5′0″. Of note, a 36-4 or 40-4 Frankle-style glenosphere provides equivalent lateralization to a 40 mm Grammont-style glenosphere and thus these columns are the same. Infra, infraspinatus.

additional length is necessary for every 6 inches (∼15 cm) of height above average. As a general rule of thumb, it is typical for a lateralized/nondisatlized Frankle-style RTSA to distalize 5 mm[14] and the corresponding column of Table IV suggests 1 mm of additional length for every 12 inches (∼30 cm) of height above average. This additional distalization could be achieved through a more distal location of the baseplate, a larger glenosphere, or an eccentric glenosphere. Again, these rules of thumb can serve only as guidelines and cannot substitute for preoperative planning of implant position and intraoperative assessment of stability and tension.

This study has several limitations. This is a retrospective study using existing data with a limited sample size. Because of the retrospective nature of the study and the lack of a priori data regarding clinically significant differences in the

**Table IV** Suggested distalization changes based on patient height

| Height | Predicted deltoid length (cm) | Distalized Grammont-style RTSA distalization (mm) | Nondistalized Frankle-style RTSA distalization (mm) |
|---|---|---|---|
| 4′6″ (137 cm) | 12.7 | −4.1 | −1.0 |
| 4′9″ (145 cm) | 13.5 | −3.1 | −0.8 |
| 5′0″ (152 cm) | 14.3 | −2.0 | −0.5 |
| 5′3″ (160 cm) | 15.2 | −1.0 | −0.3 |
| 5′6″ (168 cm) | 16.0 | 0.0 | 0.0 |
| 5′9″ (175 cm) | 16.8 | 1.0 | 0.3 |
| 6′0″ (183 cm) | 17.6 | 2.0 | 0.5 |
| 6′3″ (191 cm) | 18.4 | 3.1 | 0.8 |
| 6′6″ (198 cm) | 19.2 | 4.1 | 1.0 |

Prior studies have suggested an average of 20 mm of distalization in the distalized Grammont-style RTSA and 5 mm of distalization in the non-distalized Frankle-style RTSA. To use this table, the surgeon should first select their implant style (Grammont or Frankle) and use that column to make their judgements. Pre-operatively, they should examine the height of the pre-RTSA patient and see which row that patient's height falls into. For instance, with a Grammont-style implant, consideration should be given to adding a +3 polyethylene for patients over 6′3″ and to seating the stem an additional 3 mm for patients under 4′9″.

measurements obtained, no a priori power analysis was conducted. Our study may thus be underpowered for some comparisons. In addition, muscle lengths were calculated in 2 dimensions instead of 3. These calculations were made so as to be comparable to radiographic measurements made pre- and postoperatively. We included patients with glenohumeral osteoarthritis who underwent RTSA, and many patients with glenohumeral osteoarthritis may have undergone anatomic total shoulder arthroplasty and thus our findings may not apply to glenohumeral osteoarthritis generally, but only the subpopulation of glenohumeral osteoarthritis preoperative to RTSA. Another limitation is that we did not make postoperative measurements to determine postoperative infraspinatus or deltoid length or lateralization/distalization.

## Conclusion

Deltoid and infraspinatus length are variable but highly correlated with patient height. These correlations suggest ∼2 mm of lateralization and distalization be added for every 6 inches (∼15 cm) of height above average for a Grammont-style RTSA to maintain equivalent deltoid and infraspinatus length.

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