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# Contralateral preoperative templating for fracture reverse total shoulder arthroplasty: technique article and case series

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A R T I C L E I N F O

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Proximal humerus fractures (PHFs) account for 5% of all fractures and have become the third most common fragility fracture.[12] PHFs are challenging to manage as the treating surgeon must consider fracture pattern, age, overall health, function, and goals of the patient. Treatment options include nonoperative, open reduction internal fixation (ORIF), intramedullary nailing, hemiarthroplasty (HA), and reverse total shoulder arthroplasty (rTSA). The most common treatment varies based on geography which is likely attributable to differences in patient population and bone mineral density.[4,20,38]

The vast majority of PHFs in the geriatric population is low energy and minimally displaced which can be successfully treated nonoperatively.[16,17] However, there are certain fractures that may benefit from surgical intervention, such as 3-4 part PHFs with significant displacement, head splitting fractures, and fracture dislocations.[12] These injuries can be difficult to manage and controversy exists in the optimal treatment for the geriatric population (aged > 65 years).[27] ORIF has been shown to have high reoperation and failure rates in the setting of osteopenia with similar outcome scores compared to nonoperative treatment.[9,24,29] High complication rates have led to reconstructive options gaining popularity. HA can achieve excellent outcomes with successful tuberosity healing but this can be unpredictable which has led to variable results.[1,8,28,35,37] While tuberosity healing does lead to improved outcomes in fracture rTSA, it is not a prerequisite for a good outcome.[7,10,15,36] Additionally, rTSA has been shown to have better functional outcomes and in some studies decreased complications compared to HA for PHFs.[3,30,34] rTSA has also shown superior results in terms of function and complications when compared to other surgical treatments.[2,12,13,17,19,25,26] A concern with rTSA is longevity and limited subsequent treatment options.[11,39] However, estimated survival rates for all comers is 94% at 10 years and one study showed 97% survival at 5 years.[13,25]

With the expanding number of geriatric PHFs and the increasing indications for fracture rTSA, more surgeons are performing this procedure. However, there is a learning curve that is estimated to be between 20 and 40 cases.[6,22,41] Some of the biggest challenges in the setting of fractures is determining appropriate humeral length, implant stability, and tuberosity repair. There are also many different theories regarding rTSA implant design which increase the difficulty in navigating this process. Templating software has proven helpful in the setting of nonfracture rTSA.[5,18,42] However, to our knowledge, there are no studies evaluating the use of a preoperative template of the contralateral shoulder for planning a fracture rTSA. It is important to recognize that there is no "one size fits all" for fracture rTSA as patient anatomy differs significantly. The information obtained from the template, when used in conjunction with the proposed surgical technique, provides an algorithmic framework that provides reproducible outcomes for a highly functional and stable shoulder unique to each patient. The

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goal of this study is to provide a technique guide for surgeons using a template of the contralateral shoulder for preoperative planning and to provide tips for a reproducible surgical technique.

## Technique

### *Templating*

X-rays are obtained of the contralateral shoulder to ensure there are no gross abnormalities. It is important to question the patient regarding any known pathology in either shoulder. A preoperative computed tomography (CT) scan is obtained of the contralateral shoulder with software-specific parameters. The scan is then uploaded to Tornier Blueprint 3D Planning software (Imascap, Plouzané, France) and templating is performed in a stepwise manner.

*Step 1: glenoid baseplate*

Our goals when templating the baseplate are to achieve an inclination angle of 0 degrees, <10 degrees of version, >95% coverage on the glenoid face, and to center the screw/post in the glenoid vault. While many patients presenting with fractures do not have preexisting arthritis or deformity, it is the author's experience that to achieve these goals and conserve bone it is helpful to use a full wedge rotated to match the apex of the deformity, which is often posterosuperior or directly posterior. The implant should be adjusted to center the central fixation in the glenoid vault (Fig. 1) and to maintain an inferior position on the glenoid face so that the baseplate is flush with the inferior margin of the glenoid.

*Step 2: determining the size of the glenosphere*

A linear measurement is made from a point selected on the most medial portion of the central glenoid (Fig. 2*A*) to a point selected on the most lateral portion of the humerus (Fig. 2*B*). A measurement <50 mm correlates with a 36-mm glenosphere, 50-55 mm with a 39-mm glenosphere, 55-60 mm a 39-mm or 42-mm glenosphere, and >60 mm is usually a 42-mm glenosphere with 3 mm of lateralization (Table 1). These correlations have been established through the surgeon's extensive review of roughly 1500 prior cases for standard rTSA and evaluation between preoperative templating and final implants with close attention to ideal range of motion (ROM) and stability. The author has encountered patients who benefit from glenosphere sizes that deviate from this suggested outline and are those with a very large humeral head. Thus, during the templating process, another linear measurement is made on the axial cut of the humeral head at its widest point from anterior to posterior (Fig. 3). If the anteroposterior humeral head measurement is >55 despite the medial to lateral linear measurement initially obtained, the surgeon will begin with a glenosphere that is of 39 or 42 mm. Implant size is important as overstuffing is common and can be difficult to analyze intraoperatively. Of note, these measurements are not used to determine if an eccentric glenosphere is used, this is based on achieving >2 mm overhang on the glenoid and maximizing humeral length without going more than 23 mm.

*Step 3: humeral component*

While some PHFs require cement fixation of the stem, the author's preferred technique is to use a diaphyseal press-fit stem. The main advantage of templating a diaphyseal press-fit stem on a contralateral CT scan is the ability to estimate the humeral length and stem size. This is accomplished by planning a humeral cut through the articular surface at the preferred version. Once the cut position is determined, the size of the humeral stem is then changed to match the diaphysis (Fig. 4). It is sometimes required

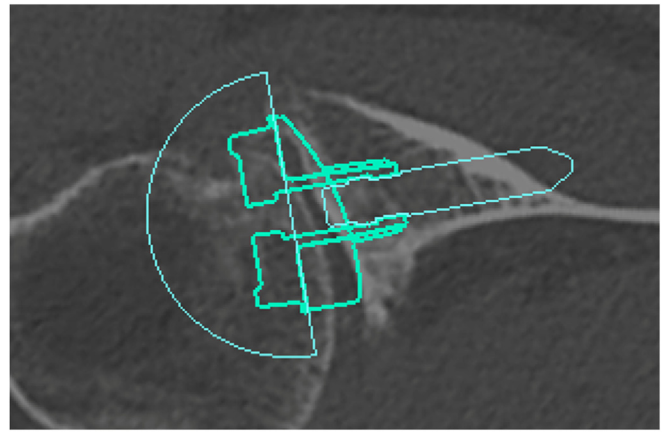

**Figure 1** Axial CT demonstrating a retroverted glenoid with a full-wedge glenoid baseplate in the apex posterior position and the central fixation device centered in the glenoid vault (Blueprint 3D Planning Software, Imascap, Plouzané, France). *CT*, computed tomography.

to use augments to build up humeral length when using a smaller stem that obtains fit more distally. Neck-shaft angle is the last modifiable portion of humeral planning. For the vast majority of patients, we use a 140-degree angle to achieve more lateralization. The surgeon may choose to deviate from this inclination depending on the body habitus of the patient and their resting arm abduction. Obese patients may benefit from a 145-degree inclination due to their inability to fully adduct their arm, whereas very thin patients may benefit from an inclination of 135 degrees.

### *Goals for lateralization and distalization*

After completion of the above steps, the software will give you global lateralization and distalization numbers. In general, for global lateralization, our goal is 3-5 mm. While controversy exists over glenoid-sided, humeral-sided, or global bipolar lateralization, it is the author's preference to medialize on the glenoid side and lateralize on the humeral side to increase the lever arm of the deltoid and achieve adequate posterior rotator cuff tension. Although, it is sometimes necessary to lateralize on the glenoid side to avoid impingement and achieve greater ROM in cases of a short glenoid neck. For distalization, our goal is to be as distal as possible without going more than 23 mm. It is the author's experience through tensioning that distalization beyond 23 mm leads to increased stress, and thus increased risk for acromial stress fractures, or an irreducible shoulder. Eccentric tray options for the onlay humerus allow fine tuning of lateralization and distalization. Finally, the software will give ROM numbers and help identify possible areas of impingement. The author's goal is at least 100 degrees of internal rotation, 50 degrees of external rotation, 100 degrees of extension, 130 degrees of forward flexion, and 90 degrees of abduction.

### *Surgical technique*

We will avoid describing every step of the technique but will highlight steps that we feel are critical in achieving good ROM while maintaining stability. A standard deltopectoral approach in the beach chair position is used.

*Soft-tissue release*

Once the intervals and humeral head are identified, blunt releases are performed under the coracoacromial ligament and

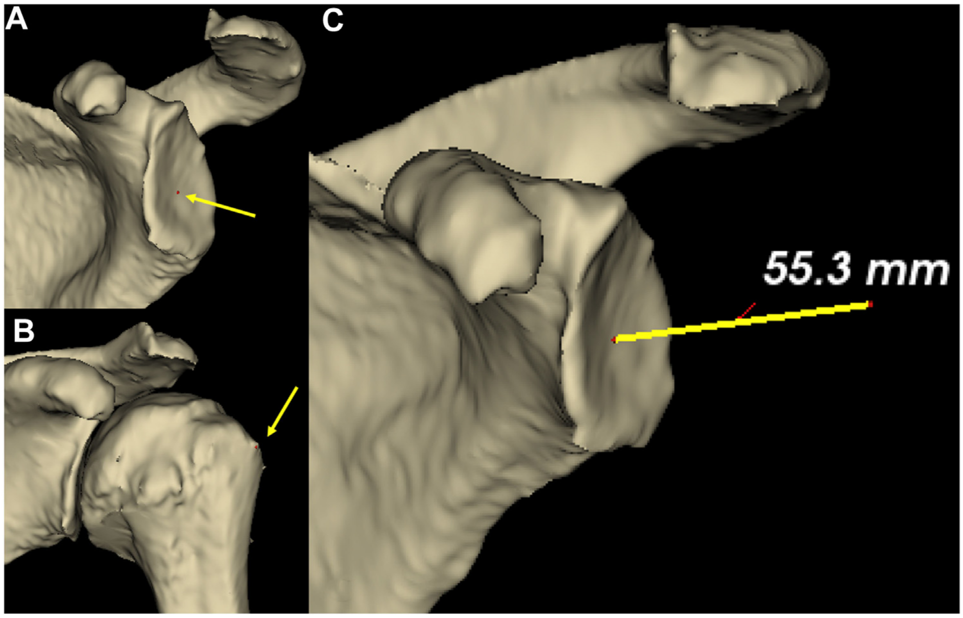


**Figure 2** (**A**) Point of measurement on the most medial portion of the central glenoid. (**B**) Point of measurement on the most lateral portion of the humerus. (**C**) Linear measurement between the 2 selected points (Blueprint 3D Planning Software, Imascap, Plouzané, France).

**Table I**
Determining trial glenosphere size.

| Mean glenoid measurements | Glenosphere size |
|---|---|
| <50 mm | 36 mm |
| 50-55 mm | 39 mm |
| 55-60 mm | 39 mm or 42 mm |
| >60 mm | 42 mm or 42 mm with +3 mm lateral augment |

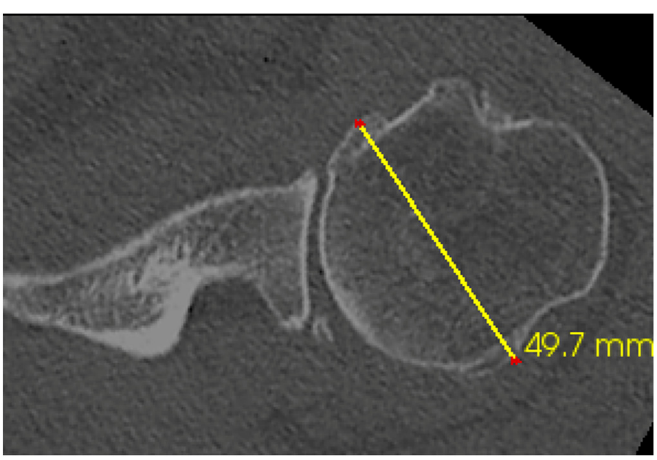


**Figure 3** Anterior to posterior measurement of the humeral head in the axial plane at its widest point (Blueprint 3D Planning Software, Imascap, Plouzané, France).

around the entire humeral head. It is important to identify and release/remove the entire supraspinatus. Some advocate for leaving the subscapularis attached to the lesser tuberosity (LT) and repairing later; however, it is the author's preference to separate the subscapularis from the LT and not repair it as to avoid over tightening. Next, the subscapularis is completely separated from the anterior capsule. At this point, it is important to palpate the axillary nerve and assess its tension and location. Over lateralizing or distalizing with a nerve already under tension can cause neuropraxia and this must be considered.[23,40,43] A circumferential release of the capsule and labrum is performed around the entire glenoid. The capsule must be completely separated from the infraspinatus and teres minor to mobilize these tendons. The triceps is also completely released from the inferior portion of the glenoid. It is important to adequately release the supraspinatus, capsule, labrum, and triceps as these soft-tissue tethers can create impingement points, restrict ROM, and give a false sense of stability.

*Glenoid and humerus preparation*

After the glenoid is exposed, the guide wire for the reamer is placed and compared to the location on the preoperative template. The goal with reaming the glenoid is to stay in subchondral bone and avoid reaming cancellous bone. It is the author's preference to have 3 peripheral glenoid baseplate screws in addition to the central screw/post when using a full wedge. Next, a trial glenosphere is placed based on the preoperative template.

The humeral canal is then exposed and prepped. Hand reamers available in 0.5 mm increments are used to decrease the risk of iatrogenic humerus fractures. With this system, the humeral stem sizes come in 2 mm increments so it is sometimes necessary to use the smaller of the 2 sizes and obtain a more distal fit in the diaphysis then augment up to the appropriate height. Depending on the fracture, it may be possible to key in the LT fragments when placing the trial implants as a reference to further confirm the desired humeral height, although this may not always be possible depending on fracture morphology and is not required to achieve stability when using the preoperative template.

*Trialing*

Tension is often difficult to assess in the setting of a fracture reverse; however, the goal is to have stability without the greater tuberosity (GT) repaired as failure is relatively common. When assessing tension, it is important to assess lateralization versus

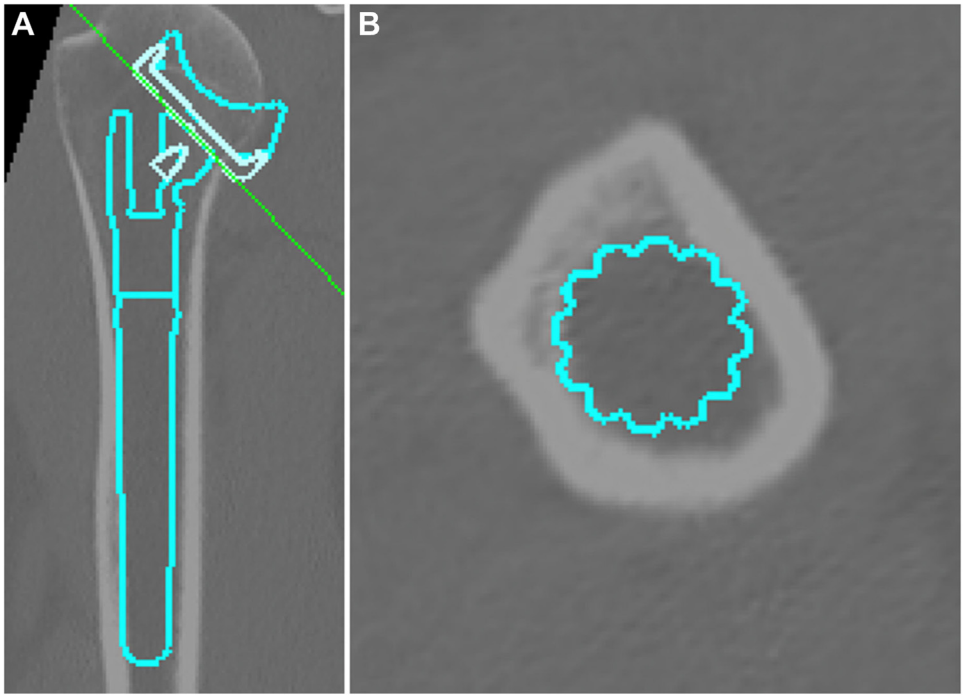


**Figure 4** (**A**) Coronal CT cut demonstrating good fit of the humeral stem and length relative to the humeral cut. (**B**) Axial CT scan demonstrating good diaphyseal fit of the humeral stem (Blueprint 3D Planning Software, Imascap, Plouzané, France). *CT*, computed tomography.

**Figure 5** Humeral head devoid of cartilage to be used as bone graft for tuberosity repair.

distalization tension. This is subjective and can be especially challenging in the setting of fractures, but an assessment is made during the reduction attempt as well as with ROM. If you trial with a standard coupling and polyethylene and the shoulder reduces without a large amount of force but maintains stability and good ROM then the humeral height is likely correct. However, if you find that you have to build up significantly on the tray and polyethylene trials then your initial humeral height may be short and should be reassessed. The conjoint tendon tension can also help gauge distalization tension, while a lateral shuck maneuver can help gauge lateralization tension. The lateral shuck maneauver is performed by placing a hand in the axillar and a hand on the lateral epicondyle of the distal humerus and levering with a varus force. If the shoulder dislocated with maneuver then it is too loose. We also suggest testing the external rotation of the contralateral shoulder prior to surgery as a reference and comparing to intraoperative external rotation. Finally, the preoperative template distalization and lateralization numbers can guide where you have room to go up or where you may be tight.

*Tuberosity repair*

Once tension has been dialed in, the height of the trial is marked, the trial implants are removed, and the final glenosphere is placed. The articular cartilage is eliminated from the humeral head that was removed during the approach and the bone is cut to size to be used as a graft for the tuberosity repair (Fig. 5). Two drill holes are made in the humerus and a nonabsorbable suture is placed through these holes to be used for the tuberosity repair (Fig. 6*A*). The final humeral implant is inserted with a nonsborable suture passed through a hole in the proximal portion of the implant. The humeral head bone graft is placed against the cortical bone of the proximal humerus to help lateralize the position of the GT piece during repair to achieve posterior rotator cuff tension; the LT is also placed around the stem and held in place with absorbable sutures (Fig. 6*B* and *C*). Next, a suture cable system is used with 2 suture cables that pass through the infraspinatus and around the GT and LT pieces (Fig. 6*D*). Once the suture cables are passed, the shoulder is reduced and the cables are tensioned to achieve circumferential compression. The reduction after tuberosity repair should have a similar feel compared with the prerepair reduction; if it feels significantly tighter then the posterior rotator cuff may not have been adequately released from the capsular tissue. Finally, the suture

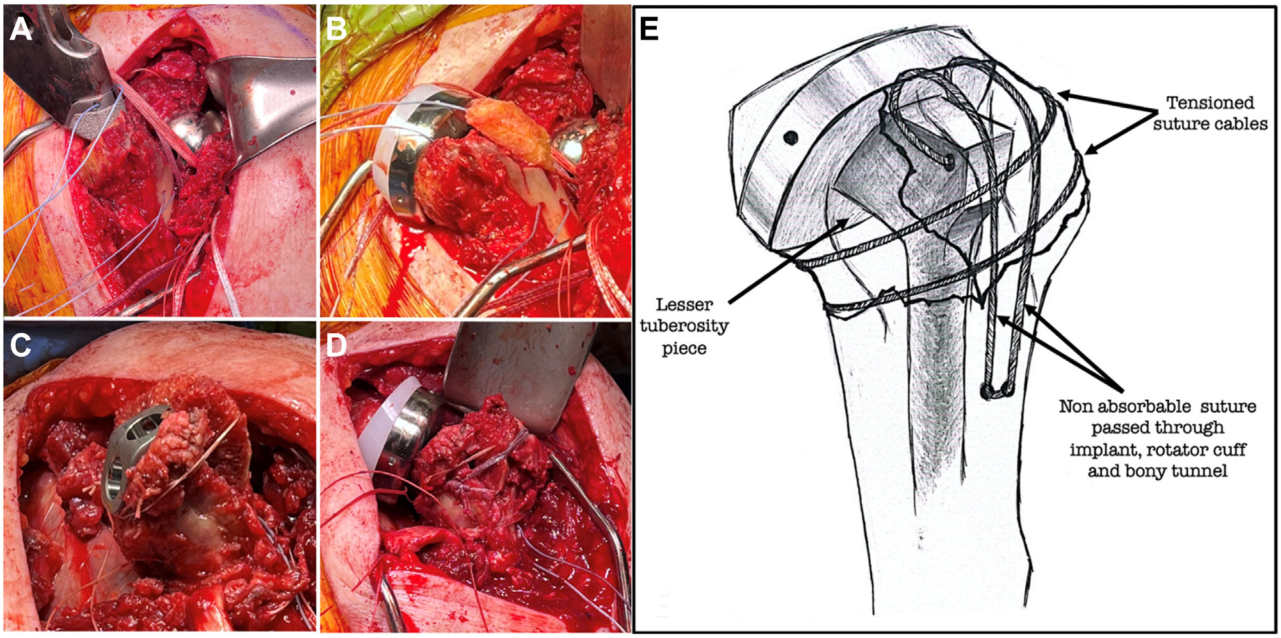


**Figure 6** (**A**) Sutures placed through humeral bone holes and the implant. (**B**) Placement of lesser tuberosity and bone graft around the stem. (**C**) Absorbable suture holding bone graft and lesser tuberosity pieces in place. (**D**) Suture cables passed through infraspinatus and around tuberosity repair. (**E**) Schematic of final repair.

from the humeral stem is tied down to the suture that was previously passed through the humeral canal drill holes (Fig. 6*E*).

*Postoperative protocol*

Postoperatively, the patients are placed in a sling with an abduction pillow. No passive or active motion is allowed for the first 2 weeks. Gentle passive ROM is allowed after 2 weeks with the aid of a pulley system. Active ROM is started 8 weeks postoperatively. Formal physical therapy focused on ROM and strength is started at 12 weeks. Radiographs are obtained at every visit and specific attention is directed to tuberosity healing.

## Clinical series

From March 2021 to April 2022, we retrospectively identified 10 patients who received an rTSA for a PHF using a template of the contralateral shoulder. With internal review board approval, we evaluated each patient after 1 year of follow-up using visual analog scale (VAS) and Constant Scores of both shoulders to use the contralateral shoulder as a control. One patient was excluded due to a primary diagnosis of proximal humerus malunion rather than acute fracture and 2 patients were excluded due to inability to find their preoperative template. Two patients did not complete 1-year follow-up; thus, Constant Scores and VAS were not recorded for these patients, but the most recent office notes were retrospectively reviewed.

The patients included 4 females and 3 males. Average age was 69 years (range 52-76 years) and average follow-up was 14.6 months (range 12-21). All patients sustained injuries classified by the Orthopedic Trauma Association (OTA/AO) as type 11-C fractures except 1 patient with a type 11-B1 in the setting of a known preexisting massive rotator cuff tear. All surgeries were performed by the senior author who has a practice dedicated mainly to shoulder pathology and performs more than 200 shoulder arthroplasties a year. Constant Scores were collected by either the senior author or a senior resident using a goniometer and a digital scale. Additionally, preoperative templates were obtained and compared to final implants.

At final follow-up average VAS was 0.48 (range 0-1.6), average Constant Score was 73.4 (range 51-87.4), and average percentage Constant Score compared to the contralateral shoulder was 97% (range 65%-117%) (Table II). Upon questioning and in chart review, there was no known pathology of the contralateral shoulder except for the patient with the type 11-B1 fracture who had severe rotator cuff arthropathy of bilateral shoulders explaining the higher Constant Score on the operative side. Upon chart review, 1 patient who did not complete final follow-up was last seen 6 months postoperatively and was found to have good ROM and strength and was satisfied with their result. The other patient who did not complete final follow-up was last seen 3 months postoperatively and demonstrated good ROM and strength and was about to start formal physical therapy. When comparing templated glenospheres and humeral stems to the final implants, we found that 6 of the 7 humeral stems did not change while only one of the glenospheres did not change (Table III). The only humeral stem that changed was due to adequate metaphyseal bone stock left that a standard metaphyseal fit stem could be implanted. This was a unique fracture dislocation where the humeral head sheared off at the anatomic neck leaving the tuberosities and most of the metaphysis intact. There is one glenosphere final implant that is omitted in Table III for an intraoperative glenoid fracture that resulted in a change to another system. An Exactech glenosphere and baseplate with an offset post were used to bypass the glenoid fracture (25%) in this case. No postoperative complications or reoperations were noted during the study period.

## Discussion

PHFs are common fractures that are increasing with the growing elderly population.[4,21,31] While nonoperative management is successful for the majority of PHFs, there are subsets of fractures that benefit from operative intervention. In the elderly population with

**Table II**
Patient outcomes.

| Age | Sex | Laterality | OTA classification | Months postoperative | VAS | Constant Score | Contralateral Constant Score | % Compared to contralateral side |
|---|---|---|---|---|---|---|---|---|
| 76 | M | Right | 11-C2 | 21 | 0 | 86 | 83.4 | 103 |
| 69 | F | Left | 11-C3 | 13 | 1.6 | 51 | 78.64 | 65 |
| 52 | M | Left | 11-C3 | 14 | 0 | 87.4 | 93.4 | 94 |
| 76 | M | Left | 11-B1 | 13 | 0.8 | 67 | 57.5 | 117 |
| 72 | M | Left | 11-C1 | 12 | 0 | 75.6 | 70.7 | 107 |
| 67 | F | Right | 11-C3 | - | - | - | - | - |
| 71 | F | Left | 11-C2 | - | - | - | - | - |

*OTA*, Orthopaedic Trauma Association; *VAS*, visual analog scale.

**Table III**
Templated sizes compared to implanted sizes.

| Template | | Final implant | |
|---|---|---|---|
| Glenosphere (mm) | Humeral stem (mm) | Glenosphere (mm) | Humeral stem (mm) |
| 42 | 15 × 130 | 42 + 3 lateralized | 15 × 130* |
| 36 eccentric | 13 × 130 | 36 eccentric* | 3B long stem |
| 36 | 9 × 130 | - | 9 × 130* |
| 36 eccentric | 15 × 130 | 42 + 3 lateralized | 15 × 130* |
| 39 | 9 × 130 | 36 | 9 × 130* |
| 39 | 17 × 130 | 42 | 17 × 130* |
| 39 | 13 × 130 | 36 eccentric | 13 × 130* |

*mm*, millimeters.
*Same size templated was implanted.

these fractures, ORIF can be challenging and have complications. The DELPHI (Delta prosthesis-PHILOS plate) trial is a recent well-designed randomized controlled trial that compared rTSA to ORIF for PHFs in the elderly and found superior functional results at 2 years with rTSA for OTA/AO-11-B2 and 11-C2 PHFs.[14] Davey et al performed a systematic review including 13 randomized controlled trials on the treatment of displaced PHFs and found that compared to other treatment modalities rTSA demonstrated lower complications and greater ROM with comparable patient-reported outcomes.[12] rTSA has demonstrated a relatively low rate of short-term revision when compared to other surgical treatments.[2,19,25] The optimal treatment is still controversial and is multifactorial for PHFs, but rTSA is becoming an increasingly popular treatment option.[33] While rTSA as a treatment option is becoming more common, it is a difficult surgery to perform and can be associated with devastating complications.

The purpose of this article is to provide a reproducible formula emphasizing the utility of combined templating and surgical technique that has been successful for us and may help surgeons perform these difficult cases. There are multiple advantages of preoperative templating of the contralateral shoulder. Severe PHFs create a daunting scenario for surgeons performing rTSA in that once you have completed your exposure you are left with a large space with obliterated anatomy that would traditionally function as landmarks. Preoperative contralateral templating provides a foundation of implants that best pair with the patients' unique anatomy. This significantly reduces the amount of guess work and trialing that goes into creating a stable shoulder. Although not evaluated in this study, reducing the guess work and trialing may also lead to less time under anesthesia for the patient. Additionally, preoperative templating provides anticipated outcomes for standard sizes on glenosphere and cup size with only minor adjustments needed intraoperatively to achieve the desired tension, stability, and ROM. It is the authors' experience that chasing height with increasing poly sizes leads to instability. Finally, using the LT to confirm humeral height is not required with preoperative contralateral templating and may be exceptionally challenging depending on fracture morphology. If the LT fragment is viable, it is considered an additional confirmation for humeral height but is not a requirement for successful placement of the humeral stem.

Our results demonstrate good outcomes but are obviously limited by such a small case series. All patients were questioned of any known pathology of the contralateral shoulder; however, with 3 patients demonstrating better Constant Scores in the operative shoulder compared to the contralateral side, it is likely that pathology exists and was not identified. It is worth noting that when compared to Constant Scores of normal shoulders based on age, 2 patients achieved normal scores, 2 patients were slightly below, and 1 patient was significantly below but did achieve 65% compared to the contralateral side.[44] Another limitation of this study is that some surgeons routinely use cement fixation of their humeral component. However, press-fit stems are increasing in popularity and have been shown to be comparable to cemented stems.[32] Additional limitations of our study are that there may be anatomic differences when comparing the contralateral side that are unaccounted for, not all companies have humeral templating, and we did not compare results to patients without a contralateral template. Finally, these are the results and technique of a high-volume shoulder arthroplasty surgeon who has been in practice for >20 years and it is difficult to capture nuances in templating and surgical technique, but our hope is that this will help guide surgeons in achieving improved results.

## Conclusion

Treatment of complex PHFs in the elderly population is controversial, but rTSA has promising short-term results. rTSA for PHFs can be extremely challenging and have harmful complications. We present a technique and case series of a high-volume shoulder arthroplasty surgeon using a CT to obtain a preoperative template of the contralateral shoulder. Utilization of the information obtained from the template in conjunction with the proposed surgical technique can aid surgeons in achieving reproducible outcomes for a highly functional and stable shoulder unique to each patient.

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