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Is preoperative planning effective for intraoperative glenoid implant size and type selection during anatomic and reverse shoulder arthroplasty?

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Introduction: Preoperative 3D planning programs for anatomic (TSA) and reverse total shoulder arthroplasty (RSA) allow the analysis of glenohumeral joint pathoanatomy and templating for implant size selection and placement. The aim of this multicenter study was to compare the preoperative glenoid implant type and size planned to the final glenoid implant type and size used intraoperatively.
Methods: Two hundred patients (100 TSA and 100 RSA) with a mean age of 72 years who had undergone preoperative planning and subsequent shoulder arthroplasty (100 TSA and 100 RSA) were included. All preoperative plans were saved and were analyzed for arthroplasty type (TSA vs. RSA), implant type (augment vs. nonaugment), and size (ie, polyethylene size, polyethylene radius of curvature, glenoid baseplate diameter, baseplate post length, and baseplate lateralization). The preoperative plan was available during surgery and was compared to the final implants inserted by the surgeon.
Results: There were no intraoperative conversions of TSA to RSA or vice versa. In patients planned for a TSA, complete concordance between the preoperative plan and final implant selection was 85%. A complete mismatch for TSA glenoid size, backside radius of curvature, and augmentation occurred in 2%. For RSA, complete concordance was found in 90% of cases. A complete mismatch for implant type, size, post length, and glenosphere size occurred in 3%.
Conclusion: A high concordance was found between preoperative 3D planning implant selection and the glenoid component inserted at surgery for TSA and RSA. This high concordance may assist with surgical preparedness, implant stocks, and possibly future implant production.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Shoulder; shoulder arthroplasty; shoulder replacement; 3D planning; planning software; reverse shoulder; anatomic arthroplasty; total shoulder

Anatomic (TSA) and reverse total shoulder arthroplasty (RSA) are viable treatment options for several degenerative conditions of the glenohumeral joint.[2,6,15,21] Patient satisfaction, pain relief, and improved function have been documented as good to excellent. However, loosening of the glenoid

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component, especially in TSA, and the radiographic phenomenon of scapular notching in RSA are major concerns in the long term.[10,13,17,25]

Recently, 3D computerized planning programs have been developed to assist with the visualization of bony deformities, understanding of the pathoanatomy, and to provide automated values for glenoid measurement indices (inclination and retroversion).[4,9] Moreover, implant size selection and placement can be trialed virtually. In addition, the computer programs can be used to calculate percentage implant seating and impingement-free range of motion. Although all of these factors can be assessed and determined preoperatively, it is unknown what the preoperative to intraoperative concordance is. Stated another way, how well does the preoperative plan predict the final implant selection? As such, the aim of this retrospective multicenter study was to analyze the preoperative glenoid plan and compare it to the final implants selected intraoperatively. The hypothesis was that there is a high concordance between planned and implanted implant types and sizes.

Methods

Patients

Between January 2017 and March 2019, a total of 200 cases that underwent shoulder replacement surgery (100 TSAs and 100 RSAs) from 3 different centers were included in this retrospective study. Each of the 3 surgeons does >100 shoulder replacement surgeries per year. Two of the surgeons work in nonacademic clinics and 1 works in a university hospital. The mean age of the patients in the TSA group was 67 years (range, 49-85 years), and there were 66 men and 34 women. The mean age of the patients in the RSA group was 75 years (range, 51-91 years), and there were 60 women and 40 men.

The inclusion criteria were as follows: patients with degenerative glenohumeral joint disease who underwent shoulder replacement surgery and had undergone preoperative clinical examination, had radiographs taken in 2 different planes, and a preoperative CT scan that was used for 3D planning. Additionally, for inclusion, all patients must have had undergone preoperative planning and had their surgical plan saved for retrospective review. The exclusion criteria were as follows: patients with incomplete preoperative imaging, an unsaved preoperative surgical plan, previous shoulder replacement surgery on the affected sides, infections, acute fractures, or neurologic diseases.

The indication for TSA was primary glenohumeral osteoarthritis in all cases. The indications for RSA were primary osteoarthritis in 53 cases, cuff-tear arthropathy in 20, massive rotator cuff tear in 20, posttraumatic osteoarthritis in 4, rheumatoid arthritis in 2, and instability arthropathy in 1.

Preoperative imaging and planning

In all cases, radiographs in 2 different views (anteroposterior and axillary) were obtained. Additionally, CT scans of the affected shoulders were done according to a standardized protocol.[27] Glenoid morphology was classified according to Walch et al[3,24] for glenohumeral osteoarthritis, rheumatoid arthritis, and posttraumatic arthritis. For shoulders with cuff-tear-arthropathy or massive cuff defects, the classification according to Favard et al was used.[5] Preoperative computerized 3D planning was performed in all cases by using the Blueprint software (Wright Medical, Edina, MN, USA). Preoperative planning was performed by each operating surgeon (G.A., P.R., G.W.), and the arthroplasty type was selected (TSA vs. RSA). Following arthroplasty type selection, the parameters of the specific implants were determined. The parameters that led to a surgeon's decision during planning was to find an implant configuration and position that maximizes range of motion and minimizes notching of the humeral component to the scapula. Osteophytes were virtually resected during planning as it is done during surgery. The preoperative planning summary was available at the time of surgery.

Surgical technique and implant types

A deltopectoral approach was used by all surgeons as previously described.[17] Throughout the procedure, the operating surgeon had the freedom to convert from TSA to RSA and vice versa. For TSA, all 3 surgeons had the same implant selection options. A cemented polyethylene glenoid (Perform; Wright Medical) component available in 4 different sizes (small, medium, large, and extra-large) with different backside radii of curvature (size small and medium: 30 mm, 35 mm, and 40 mm; size large and extra-large: 40 mm, 50 mm, and 60 mm). Additionally, for TSA, a posterior augmented component was available (Perform Plus; Wright Medical). The posterior augmented polyethylene implant is available as small, medium, large and extra-large, with each size having 3 additional augment sizes (15°, 25°, and 35° half wedges). As such, for TSA glenoid options, a total of 24 different implant choices were available to the surgeon. A detailed distribution of implants used is shown in Table I.

For RSA, 2 different glenoid systems were available. The standard glenoid baseplate system (Reverse II; Wright Medical) is available in 2 diameters (25 mm and 29 mm) and 2 central post lengths (15 mm and 25 mm). Three glenosphere size options are available for the standard baseplate (36, 39, 42 mm). All glenospheres are also available with inferior eccentricity for an inferior overhang to limit scapular notching. As such, for the standard system, 4 baseplate options exist and 6 glenosphere options. The second glenoid RSA system available contained baseplate augments (Perform Reverse; Wright Medical); it is also available in 2 diameters (25 and 29 mm). Additionally, 2 augment styles are available for each diameter, a half-wedge and a full-wedge

Table I Distribution of glenoid component sizes and radiuses

Glenoid size	Backside radius of curvature, mm					Posterior augment			Total
	30	35	40	50	60	15°	25°	35°	
Small	0	1	10	NA	NA	5	5	0	21
Medium	3	2	14	NA	NA	14	9	0	42
Large	NA	NA	2	0	4	6	10	3	25
Extra-large	NA	NA	2	0	4	5	1	0	12
Total	3	3	28	0	8	30	25	3	100

NA, not applicable.

augment. Similar glenosphere options exist for the augmented system, 36-, 39-, and 42-mm diameter with and without eccentricity. Therefore, for the augmented options, 4 baseplate options existed and 6 glenosphere options. As such, for RSA glenoid options, a total of 8 different baseplate choices were available to the surgeon and 6 glenosphere options. A detailed distribution of implants used is shown in Table II.

Statistics

Descriptive statistics were used and the total number or percentages are given. Unpaired *t* test was used to analyze the difference between the percentage of perfect matching between the TSA and RSA groups. A P value $\leq .05$ was considered to show a statistically significant difference.

Results

There was 100% concordance on arthroplasty type between the preoperative plan and the intraoperative implant selected. As such, there were no intraoperative conversions of a TSA to RSA or vice versa.

TSA group

The glenoid morphology in the TSA group was classified as Walch A1 in 29%, A2 in 10%, B1 in 13%, a B2 in 42%, B3 in 5%, C in 0%, and D in 1%. The mean glenoid retroversion in this group was 12° (range, −8° to 37°) and mean inclination was 8° (range, −15° to 20°; positive inclination corresponds to superior inclination). The mean posterior humeral head subluxation was 71% (range, 44%-94%). In 92 cases, a keeled glenoid component and in 8 cases a pegged component with 4 pegs was used. The central peg had radial fins, and all components were fully cemented.

In 85% of cases, there was complete concordance between the preoperative plan and the implanted anatomic glenoid component (implant size, backside implant radius, and the use and size of a posterior augmented implant). In 96% of cases, the planned implant size was used and in 91% of cases the planned backside implant radius was used. Regarding the 4 cases without matching of the implant size, the difference was not greater than 1 size (in 1 case from small to medium, in 1 from medium to small, in 1 from large to extra-large, and in 1 from extra-large to large). Regarding the backside radius of curvature, there was a difference of only 1 size in 2 cases and a difference of 2 sizes in 7.

In 58 cases, a posterior augmented component was planned and also implanted. However, in 2 cases an augmented component was planned but a standard component was implanted, and in another 2 cases a standard component was planned but an augmented glenoid was inserted. There was a 98% concordance between the planned size of the posterior augment and the implant inserted. The implant parameter that had the poorest concordance (9%) between the preoperative plan and the intraoperative implant used was the backside radius of curvature. A complete mismatch for implant size, backside radius of curvature, and augmentation was present in 2%. In those 2 cases, there was a difference of 1 size for the implant as well as 1 size for the backside radius of curvature. In one of these cases, a posterior augmented component was planned but a standard component was implanted. Nonconcordance of implant size, posterior augmentation, or backside radius of curvature resulted after

Table II Distribution of glenoid component sizes and radiuses

Baseplates	Standard glenospheres, mm			Eccentric glenospheres, mm			Total
	36	39	42	36	39	42	
Reverse II baseplates							
25/15 mm	0	0	0	2	0	0	2
25/25 mm	18	7	0	23	1	0	49
29/15 mm	0	0	1	0	0	3	4
29/25 mm	0	2	15	3	2	5	27
Perform Reverse baseplates							
25 mm	0	0	0	1	0	0	1
25/+3 mm	0	1	0	0	0	0	1
25/+6 mm	0	0	0	0	0	0	0
29 mm	0	0	0	0	0	0	0
29/+3 mm	0	0	0	0	0	0	0
29/+6 mm	0	0	0	0	1	0	1
Perform + Reverse baseplates							
25 mm half wedge	0	0	0	0	0	0	0
25 mm full wedge	3	2	1	0	0	0	6
29 mm half wedge	0	0	0	0	0	0	0
29 mm full wedge	0	0	3	0	1	5	9
Total	21	12	20	29	5	13	100

intraoperative measurement of the glenoid surfaces with the gauges, sizers, and trial components. If there was a discrepancy between intraoperative measurement and planning, the surgeons decided to use the implant that had the best fit to the intraoperative measurements.

RSA group

For the 60 cases with primary osteoarthritis, rheumatoid arthritis, and post-traumatic arthritis, an A1 glenoid morphology was present in 16 cases, an A2 in 11, a B1 in 5, a B2 in 15, and a B3 in 13. The remaining 40 cases with cuff tear arthropathy or massive cuff defects had an E0 glenoid morphology in 30 cases, an E1 in 3, and an E2 in 7.

Mean glenoid retroversion in the RSA group was 12° (range, −15° to 45°), and mean inclination was 10° (range, 0°-25°). Mean posterior humeral head subluxation was 67% (range, 11%-95%).

In 90% of cases, there was complete concordance between the preoperative plan and the implanted RSA glenoid components (types and diameters of the baseplates, length of the posts, and bone or metal augmentation). The preoperatively planned type and diameter of the glenoid baseplate was used in 94% of cases. A baseplate with a long central post was used in 76 cases in combination with an autograft from the humeral head to lateralize the center of rotation on the glenoid side (BIO-RSA). Size and eccentricity of the glenosphere matched in 93% of cases to the planning. In case of nonconcordance of the glenosphere, there was only a 1-size difference, and this implant parameter had the poorest concordance between the preoperative plan and the intraoperative implant used. A complete mismatch for implant type, size, post length, and glenosphere occurred in 3%. In those 3 cases, there was a difference of 1 size for the baseplate as well as 1 size for the glenosphere.

There was no significant difference between the percentage of perfect matching between the TSA and the RSA group ($P = .29$).

Discussion

The indications for shoulder arthroplasty have evolved during the last few decades, and the numbers of implantations are increasing continuously. The indications for RSA have far expanded the initial usage in elderly patients with cuff deficiency.[14] The array of pathologies that RSA can address has also far surpassed that of TSA. Common indications for RSA now include trauma,[1,7,26] sequelae of trauma,[11,12,16,18-20,26] osteoarthritis with bone loss,[14] revision arthroplasty,[22] and tumor reconstruction.[8,23]

Hoping to decrease complications related to implant size and position, computerized 3D planning programs were developed for shoulder arthroplasty. These software-based tools are able to digitally reconstruct the shoulder joint by using data from CT scans. Additionally, computer algorithms have been developed that can reproducibly calculate glenoid version and inclination, which can assist with classification and understanding of the pathoanatomy. Most commercially available programs allow for the virtual implantation of TSA and RSA implants to assess for position, implant seating, and degree of reaming. Additionally, range of motion can be examined by perimeter bony impingement tests.[4] It has been shown that fully automated 3D planning tools may improve preoperative planning, gain time for the surgeon, and eliminate inter- and interobserver discrepancies.[4] Overall, there are several theoretical advantages to using preoperative planning programs. There are disadvantages as well, including increased time and potentially cost.

Unfortunately, with all the theoretical advantages of preoperative 3D planning, there is limited to no literature assessing the concordance between the preoperative plan and the final implant selection. As such, that was the motivation for our study, which, after data analysis the results demonstrated a high concordance between the preoperatively templated glenoid implants and the final implants used during surgery. The anatomic glenoid system used in this study offered 16 different glenoid components; hence, a concordance of 85% (perfect match) was considered high. The reverse glenoid system used also had a large number of different implant configurations; therefore, a concordance of 90% was also considered as high.

The high degree of concordance between the preoperative plan and the final implant selection has several potential benefits. One benefit could be to reduce implant options shipped to hospitals for particular cases. Presently, industry representatives ship all potential implant sizes to hospitals before surgery, which results in increased shipping costs, hospital storage issues, and the sequestering of implant sizes that may be required elsewhere. An option would be to have surgeons preoperatively plan and then to ship the implant selected and the adjacent sizes to capture all possibilities. Another potential benefit with preoperative planning is for surgical preparedness, having the staff in the operating room ready with the appropriate-sized instruments and reamers to optimize efficiency.

One limitation of this study is the retrospective design. Moreover, a surgeon may be compelled to adhere to the plan to improve concordance, thereby introducing bias. The findings of this particular study are not generalizable as only 1 planning software and implants from 1 manufacture were used.

Conclusion

A high concordance was found between preoperative 3D planning implant selection and the final glenoid component inserted at surgery for TSA and RSA. This high concordance may assist with surgical preparedness, implant stocks, and possibly future implant production.

Disclaimer

George Athwal is a consultant for Wright Medical-Tornier Inc and Exactech.

Gilles Walch and Patric Raiss are consultants for Wright Medical-Tornier Inc. Neither company had any input in the study design, protocol, testing, data analysis or manuscript preparation.

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