The use of preoperative planning to decrease costs and increase
efficiency in the OR

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Background: Shoulder arthroplasty (SA) incurs up to $1.88 per year in societal costs. With the increasing demand for SA and the steady decrease of annual reimbursements for orthopedic procedures, it has become crucial to control costs. In SA, there has been an interest in using preoperative planning software to improve accuracy in positioning and implant selection, ultimately optimizing outcomes. However, the use of preoperative planning to increase efficiency has not been studied. The purpose of this study was to determine if preoperative planning could increase efficiency and decrease costs in the operating room.

Methods: This retrospective review included 94 patients who underwent shoulder arthroplasty and had a CT scan with a preoperative plan by a single orthopedic surgeon between 2017 and 2020. The patients were divided based on the use of the preoperative plan during surgery. Group 1 included 65 patients with a preoperative plan used during surgery, and group 2 included 29 patients without a preoperative plan utilized during surgery. Average preparation time, surgical time, time in the operating room, the number of trays sterilized, and postoperative outcomes were analyzed between the two groups. Sub-analysis was done to find a statistical difference in the cost of sterilization for both groups.

Results: The cohort had 55% males, with an average age of 71 years and an average BMI of 29.9. There were no significant differences between the groups for age, BMI, or ASA class. There was no significant difference between groups in preparation time (group 1: 53.3 min, group 2: 53.1 min $P = .924$), surgical time (group 1: 119.7 min, group 2: 111.9 min; $P = .25$), or time in the OR (group 1: 183.2 min, group 2: 173.2 min; $P = .156$). There was a statistical difference in the number of trays (5 vs. 8; $P < .01$) and cost of sterilization between groups ($487.30 vs. $842.86; P < .01$). No correlation between the number of trays and preparation time (group 1: $r = -0.05$, group 2: $r = -0.28$) or trays and surgical time was found for either group (group 1: $r = -0.31$, group 2: $r = -0.22$). There were no significant differences in postoperative outcomes between the groups.

Conclusion: While preoperative planning did not reduce time in the OR for shoulder arthroplasty, it was correlated to a significant reduction in the number and cost of sterilized trays with comparable postoperative outcomes.

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With the increasing demand for shoulder arthroplasty and the steady decrease of annual reimbursements for orthopedic procedures, it has become crucial to control costs and improve efficiency. Total shoulder arthroplasty has been shown to incur up to $1.88 per year in societal costs. Insurance providers have focused on one method to provide significant cost savings through lowering average days of inpatient hospital admissions, limiting hospital stays and transition to ambulatory surgery setting for total joint replacements. Interest on lowering costs now has now focused on limiting implant selection, optimizing implant pricing, and decreasing the use of hospital resources and operating room (OR) time.

Careful preoperative planning can reliably measure pathology, guide intraoperative implant selection, and improve correction of pathology in shoulder arthroplasty. In addition, three-dimensional preoperative planning software has demonstrated accuracy in predicting intraoperative implant selection in reverse shoulder arthroplasty (RSA) and total shoulder arthroplasty.

This study was performed under the approval of the Cleveland Clinic Institutional Review Board (FLA 17-054).

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Additionally, 3D templating can potentially improve surgeon efficiency through quick and reproducible planning and reduce costs associated with bringing excess components such as surgical trays into the operating room.

Health care costs in the United States have continued to climb and represent a serious concern to societal infrastructure. Currently, the incidence of shoulder arthroplasty procedures is also increasing at a greater rate than total hip and knee arthroplasty.20-22 Although limited studies have demonstrated reduced costs for templating software and template-directed instrumentation for total knee replacement,22 studies have not shown the same cost-effectiveness of using patient-specific instrumentation shoulder arthroplasty procedures.2 The purpose of our study is to assess how preoperative planning in SA could impact surgical efficiency and intraoperative costs. We hypothesize that, given the accuracy of preoperative planning, it can lead to decreased costs and increased efficiency in the operating room for SA.

Methods

Patient cohort

This retrospective study consisted of 94 patients that underwent either a primary total shoulder arthroplasty (TSA) or reverse shoulder arthroplasty (RSA) between 2017 and 2020 and had a 3D CT scan with a preoperative plan. Patients were split into two groups: Group 1 included patients with a 3D preoperative plan without PSI that was used during surgery to guide treatment and implant selection, and Group 2, the control group, included patients who underwent SA without the use or review of the 3D preoperative plan during surgery. Group 2 was collected from 2017 to 2018; during this time, the surgeon did not utilize the plan to guide implant selection or surgical execution. Our intervention group (group 1) had a plan that the surgeon used specifically to guide implant selection while operating; it was followed and utilized during surgery, whereas the control group had a plan that was reviewed; however, the surgeon did not use it to guide and restrict the trays or implants that were brought into the OR. All patients underwent a preoperative plan as a standard of care for this surgeon and patients in group 1 were collected from 2018 to 2020; given the published accuracy of 3D templating software 1,3,11-13 to guide addressing pathology and implant selection, the surgeons changed their practice to base the intraoperative plan and implant selection off of the preoperative planning software selections. This practice evolution was applied for all shoulder arthroplasty patients to minimize any bias in patient selection.

Preoperative planning and surgery

CT studies followed a specific standardized protocol (120 kV, 140mAs, 0.6-mm collimation, 134 512 × 512 matrix, no gantry tilt, and 50-cm field of view, fine cut) to allow for proper software modeling. Then Digital Imaging and Communications in Medicine (DICOM) files of each CT scan were uploaded into Tornier Blueprint 3D Planning (Wright Medical Inc., Memphis, TN, USA) software to preoperatively plan the surgery. Optimal image reconstruction was achieved by using a semismooth algorithm, B40, at 0.6-mm axial increments.1 Glenoid pathology was classified in the axial plane according to the Walch classification.2

When planning, multiple variables were adjusted repeatedly, and only 1 preoperative plan was finalized, as the software does not allow for several saved plans to coexist on a singular patient case. On the humeral side, the humeral head cut was chosen based on the procedure performed and recommended a 132.5° angle for RSA at the optimal height of the head-neck junction. Although the epicondyles were not included in the CT scan, Blueprint is an automated program that uses specific image recognition sequences with three-dimensional landmarks to identify the scapula from the humerus and aid in the automated measurement of version and inclination.8 The goals of planning on the glenoid side were to optimize implant seating, pathologic correction, implant sizing, and central screw fixation. In cases of severe retroversion, we employed a combination of an augmented glenoid implant and high side reaming based on standard principles to correct the pathologic version to less than 6° of retroversion and optimize greater than 90% backside seating. A Bony Increased Offset (BIO) RSA was not used in any of our cases, and all implants were from Wright medical as implants from other manufacturers were not compatible with the planning software. Glenosphere size, eccentricity, and laterality were selected to optimize the above guidelines and passive range of motion (ROM) based on baseplate compatibility.

The patient-specific preoperative plans were reviewed and executed in Blueprint by the operating surgeon and blueprint outputs were recorded. The preoperative templated plan was used as a guide for intraoperative tray usage and implant selection for the intervention group; however, final intraoperative implant selection was always based on patient bone quality, glenohumeral anatomical size, soft tissue definition (muscle quality and muscle tension), and fit determined by the training, expertise of the senior operating surgeon. Sabesan et al. has previously validated this software’s ability to reliably predict and plan intraoperative implant selection with a great degree of accuracy using the same methodology described here.20,21

Surgical technique

All cases were performed by single fellowship-trained shoulder surgeon at a single institution in a semi beach-chair position using a standard deltopectoral approach. The biceps tendon underwent tenodesis to the pectoral major tendon. A tenotomy of the subscapularis was made, and the subscapularis tendon and anterior capsule were released off the glenoid. The humeral head was resected respecting the native humeral head version and inclination. The humeral shaft was prepared with optimal humeral coverage for the humeral tray. The glenoid retroversion and implant placement and/or size were assessed with the 3D preoperative plan for the intervention group, and then correction and implant size final selections were made based on intraoperative surgical decision-making. Trial components were placed, and once the soft tissue tensioning and stability were trialed and tested, the final components were implanted.

Data collection

An IRB-approved prospectively collected database was retrospectively reviewed, which contained SAs performed by a single surgeon from a single academic institution. Basic demographic information was collected from electronic medical records, including, but not limited to, age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) scores, diagnosis, comorbidities, and affected side.

The database was reviewed to collect time variables from the operating room (OR), number of trays, and cost of sterilization. Times for each case were recorded in minutes at different periods to find total surgical time (incision to closure), total time in the OR (time into room to time out of room), and preparation time (time into room to incision time). The total number of trays was calculated based on the manufacturer’s trays prepared for and opened for the case determined by the surgeon’s request. For example, if the case was posted for TSA vs. RSA or standard vs. augmented...
components, all the trays would have been opened rather simply TSA or augmented RSA, which did occur when the preoperative plan was used specifically as a guide in surgery. Instrumentation trays were not included in the number of trays used for sterilization as this is standardized for all primary SA cases and exists on the shelf. The cost of sterilization per case was calculated by multiplying the standard cost of sterilization per tray at our institution of $100 by the number of trays used. Confounding variables such as Glenoid inclination, version, and Walch classification were included to account for the degree of difficulty of surgery. Patient outcomes, function, and pain frequency were recorded with a minimum 3 months follow-up. The range of motion at the most recent patient follow-up available was recorded, including external rotation, internal rotation, abduction, and flexion.

Statistical analysis

Statistical analyses included the T-test, ANOVA, and Pearson’s correlation with a $P < .05$ defined for significance. Potential confounding variables were explored in subanalyses using glenoid type and surgical time for both groups. Statistical analysis was conducted using SPSS 24.0 software (IBM, Armonk, NY, USA).

Results

Ninety-four patients met inclusion criteria and were divided into their two respective groups based on the use of preoperative planning software intraoperatively. Group 1 consisted of 65 patients, and the control group (group 2) included 29 patients. The two groups were comparable at baseline as there was no significant difference in age, gender, BMI, ASA class, number of comorbidities, and affected arm between groups (Table I). The groups were also comparable in glenoid version and inclination, preoperative range of motion (Table I), and preoperative patient-reported outcomes (Table II).

| Table I | Comparison of baseline characteristics, preoperative measurements, and function between groups. |
|-------------------|-----------------------------------------------|
| **Average age** | 71 ± 8.8 | 69.8 ± 9.5 | 0.577 |
| **Male (%)** | 35 (54) | 16 (55) | 0.966 |
| **BMI (kg/m²)** | 29.7 ± 6.5 | 30.3 ± 6.7 | 0.727 |
| **Average ASA score** | 2.6 ± 0.6 | 2.4 ± 0.6 | 0.167 |
| **Average number of comorbidities** | 2.7 ± 1.5 | 2.8 ± 1.4 | 0.847 |
| **Right arm (%)** | 25 (38) | 13 (45) | 0.695 |
| **Glenoid version (°)** | −11.1 ± 17.6 | −16.4 ± 12.5 | 0.269 |
| **Glenoid inclination (°)** | 7.1 ± 11.5 | 5.9 ± 8.3 | 0.701 |
| **Flexion (°)** | 154.8 ± 21.4 | 156.1 ± 27.1 | 0.833 |
| **Abduction (°)** | 149.1 ± 27.0 | 160.4 ± 20.5 | 0.058 |
| **External rotation (°)** | 44.3 ± 20.1 | 44.8 ± 23.1 | 0.918 |

BMI, body mass index; ASA, American Society of Anesthesiologists.

| Table II | Preoperative patient outcomes compared between groups. |
|-------------------|-----------------------------------------------|
| **Group 1** | **Group 2** | **P value** |
| **NRS now** | 5.9 ± 3.6 | 5.0 ± 3.5 | 0.404 |
| **NRS at rest** | 4.3 ± 3.5 | 2.8 ± 3.0 | 0.154 |
| **NRS normal activity** | 7.7 ± 3.4 | 6.7 ± 2.9 | 0.33 |
| **NRS strenuous activity** | 8.3 ± 2.8 | 8.2 ± 2.9 | 0.457 |
| **ASES pain** | 20.4 ± 17.9 | 25 ± 18.0 | 0.404 |
| **Penn pain** | 20.7 ± 8.3 | 17.7 ± 7.4 | 0.232 |
| **Penn satisfaction** | 9.3 ± 8.2 | 13.5 ± 7.4 | 0.086 |
| **Penn function** | 10.5 ± 9.4 | 15.1 ± 10.6 | 0.162 |
| **ASES function** | 11.5 ± 9.4 | 145 ± 95 | 0.319 |

NRS, numerical rating scale; ASES, American Shoulder and Elbow Surgeons; SSV, Subjective Shoulder Score.

| Table III | Intraoperative data comparison between groups. |
|-------------------|-----------------------------------------------|
| **Group 1** | **Group 2** | **P value** |
| **Surgical time (min)** | 118.2 ± 26.2 | 111.9 ± 27.2 | 0.252 |
| **Operating room time (min)** | 183.2 ± 32.1 | 173.2 ± 30.3 | 0.160 |
| **Preparation time** | 53.5 ± 18.9 | 53.1 ± 20.3 | 0.924 |
| **Number of trays** | 4.9 ± 0.3 | 8.4 ± 2.9 | <0.001* |
| **Cost of sterilization ($)** | 487.30 ± 34 | 842.86 ± 290 | <0.001* |

*Denotes significance ($P < .05$).
translating into a significant reduction in sterilization cost and lesser number of trays needed per case. Studies have confirmed optimizing surgical tray use during a procedure can reduce cost, preparation time, and increase operating room efficiency. The accuracy of 3D preoperative planning has correctly predicted the size of SA components and glenoid measurements used intraoperatively. Thus, it is possible to minimize the number of instruments and trays used in a shoulder arthroplasty procedure based on the use of preoperative planning.

Previous literature has shown the majority of short-term costs with SA are operative costs and can be attributed to implant-specific costs, which is a modifiable factor. In this study, we were unable to compare cost of implants, as a single system was used with set institutional pricing for the type of case. In addition, RSA has been shown to be more expensive than TSA mainly due to costlier implants. Since our cohort overall had significantly more patients undergoing RSA than TSA, this variable could not be compared for surgical costs and operative time. Although our study could not incorporate implant costs, it does examine continuous process improvement strategies with surgical trays. Cost-saving was appreciated with a 42% decrease in sterilization cost associated with preoperative planning use. Previous studies have highlighted the impact of this method on reducing operating room costs, most notably in hip and knee arthroplasty, where tray optimization resulted in an annual savings of $159,600 in sterile processing costs. To our knowledge, our study is the first to analyze sterilization cost savings using preoperative planning for shoulder arthroplasty.

Limitations of this study included a small sample size and quality of the OR data that limited our ability to analyze confounding factors. In addition, the cohort sizes were not equally based on the surgeon’s practice evolution and available data. There was, however, no selection bias, given that all patients underwent preoperative planning regardless of pathology or patient characteristics. With an increased sample size, our study may have had the power required for the small differences in types of surgery, patient factors, variations in minutes, and costs that may have been statistically significant. Numerous confounding variables across institutions such as the presence of consistent teams, specialized services, fellows, residents, and medical students can drastically change both surgical cost and surgical time. Time allocated to dynamic education or specialized teams in the OR is not recorded in hospital systems but should be integrated to accurately evaluate and understand operating time and costs. Moreover, hospital tracking of additionally needed instruments and problems with sterilization or case delays was not available to be studied.

Advancements in OR tracking, from both a provider and hospital perspectives, could result in a reduction of prospective costs. With ongoing improvements in OR tracking and sterilization systems, further improvements are expected. Preoperative planning is an efficient tool which can be utilized for cost savings in ORs, and such planning can be increased with 3D planning software that takes advantage of the preoperative phase for improving efficiency.

Focus has risen on surgical costs and efficiency through enhancing surgical tray usage. In our study, the use of preoperative planning did significantly decrease the number of trays, directly resulting in a reduction in sterilization cost and a lesser number of trays needed per case.
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