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Preliminary Clinical Outcome of Virtual Surgical Planning to Assist Reverse Total Shoulder Arthroplasty

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Abstract

Introduction Complex proximal humerus fractures in elderly are preferably treated with reverse total shoulder arthroplasty (RTSA). We hypothesized that patients with proximal humerus fractures benefit from virtual surgical planning (VSP) to overcome complication. Therefore, the aim was to investigate clinical outcome of RTSA with preoperative VSP compared to treatment without VSP.

Methodology A cohort study was performed comparing two groups: RTSA with VSP (after June 2022) vs. RTSA without VSP (before June 2022). Patients were included if planned for only a RTSA for an acute fracture within 28 days after trauma. The primary outcome measure was the range of motion (ROM) assessed for abduction, forward elevation and external rotation. The secondary outcome measures were complication rate, Patient Reported Outcome Measures (PROMs), operating time (minutes), and stem height of the prosthesis (mm).

Results Thirty-four patients were included with 27 in the RTSA with VSP group and 7 in the RTSA without VSP. Within this interim analysis, no significant differences were found between the groups for ROM, complication rate, PROMs. Significant differences were found in favor of RTSA with VSP for operating time and stem height

Conclusion Preliminary data show some benefits using VSP for RTSA, but full data collection is needed to confirm positive effect on clinical outcome.

1 Introduction

Complex proximal humerus fractures in elderly are preferably treated with reverse total shoulder arthroplasty (RTSA) [1]. RTSA replaces both the humeral head and the glenoid surface of the shoulder joint, with a reversed anatomic configuration of the convex and concave implant components[2]. This

gives the advantage of being less dependent on functionality of the rotator cuffs, and allowing a larger range of motion [3]. RTSA is a challenging technique prone to complications such as infection, component loosening, scapular notching, instability, periprosthetic fracture, acromial stress fractures, and implant wear [4].

Especially, positioning of the RTSA components is challenging as fracture patterns change the position of anatomical landmarks, such as the greater and lesser tuberosity and the anatomical neck [5]. Virtual surgical planning (VSP) can assist in achieving optimal implant position [6]. Figure 1 shows the workflow of this virtual surgical planning which provides information on the optimal size, stem height position, and tuberosity fixation. We hypothesized that patients with proximal humerus fractures benefit from VSP for RTSA. Therefore, the aim was to investigate clinical outcome after reverse total shoulder arthroplasty with preoperative virtual surgical planning compared to conventional surgical intervention in patients with proximal humerus fractures using only medical imaging.

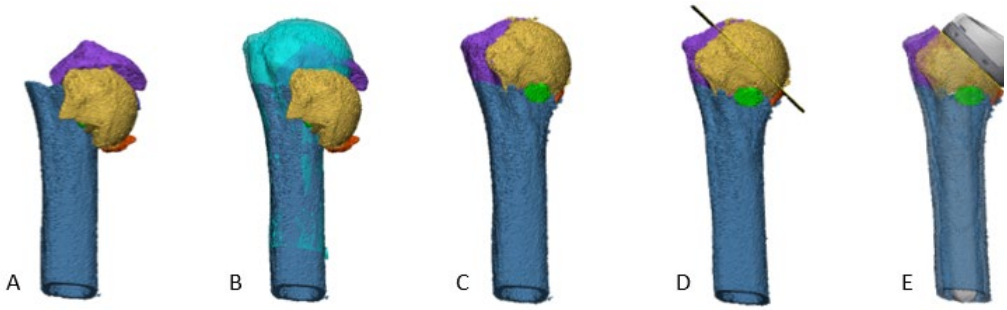

Figure 1: Virtual surgical planning for reverse total shoulder arthroplasty in proximal humeral fractures. A) Segmentation and 3D visualization. B) Mirror and alignment of contralateral side. C) Reposition of fragments including tuberosities. D) Determination resection plan. E) Selection of stem size and position of prosthesis.

2 Methodology

A cohort study was conducted comparing two groups: patients who underwent RTSA with VSP after its introduction in June 2022, and patients who underwent RTSA using a radiograph and CT-scan without any additional preoperative planning or medical image processing (RTSA without VSP) before June 2022 at the Medical Spectrum Twente. Approval was received from the institutional review board of Medical Spectrum Twente (K22-24) to include 78 patients, which was determined from a power analysis. The inclusion criterion was patients treated with RTSA for an acute fracture within 28 days after trauma. The exclusion criteria were insufficient follow-up (< 1 year), absence of postop clinical evaluation and radiographs, pre-existing deformities of the fractured proximal humerus. Collected patient demographics were gender, age, medical history, BMI, and smoking.

The primary outcome measure was the range of motion (ROM) assessed for abduction, forward elevation and external rotation. The secondary outcome measures were complication rate, Patient Reported Outcome Measures (PROMs) assess by the Oxford Shoulder Score [7], the Simple Shoulder Test [8] and a Numeric Rating Scale for pain, operating time (minutes), and stem height of the prosthesis (mm).

The optimal stem height was preoperatively planned by creating a VSP executed in 3Matic software (v. 25.0 Materialise, Leuven, Belgium). For fair comparison, first VSPs were generated postoperatively for the group RTSA without VSP using the preoperative CT-scans, and second from all VSPs digitally reconstructed radiographs were created. This allowed measurement of the stem height in the same way

as the postoperative anterior-posterior radiographs on which the actual achieved stem heights were measured. The measurement itself was done as follows. First, calibration was performed by measuring the humeral tray of the prosthesis with a known diameter of 44 mm. Second, the stem height was measured from the upper tip of the wing to the highest lateral spike of the humerus shaft, in the direction of the prosthesis stem. Third, this measurement was repeated three times and the average value was used in data analysis.

The outcome measures range of motion, PROMs and operating time were expressed in means and standard deviations and statistically investigated with a t-test to compare both groups ($p < 0.05$). The complication rate was expressed as percentages and statistically investigated with a chi-square test ($p < 0.05$). The mean actual postoperative stem height was subtracted from the planned stem height on the VSP, visualized in a Bland-Altman plot, and statistically investigated with a t-test to compare both groups.

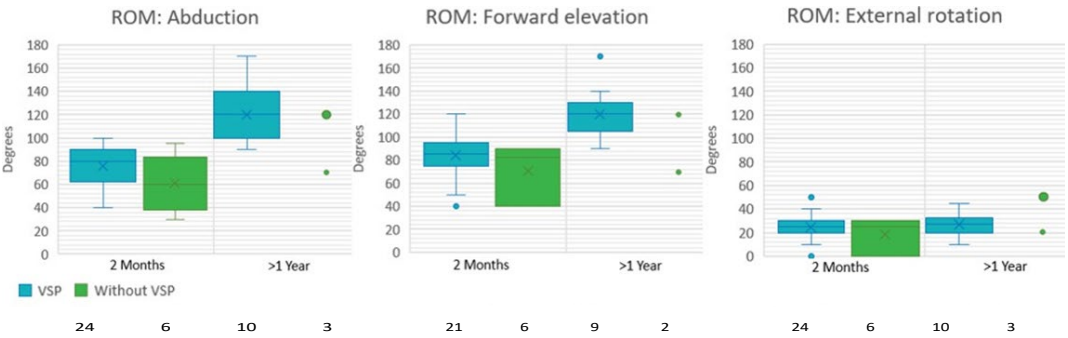

Figure 2: Box plots of ROM for abduction, forward elevation and external rotation for both groups. The number of patients vary per time stamp and ROM, as indicated in the bottom row.

3 Results

Thirty-four patients were included with 27 in the RTSA with VSP group and 7 in the RTSA without VSP. The RTSA with VSP group had 85% females, and a mean age of 71.5 years (± 7). The RTSA without VSP group had 86% females, and a mean age of 69.7 years (± 7). The patient characteristics show no significant differences between both groups.

ROM in abduction, forward elevation, and external rotation showed no significant differences between the two groups at both 2-month and >1-year follow-up (Figure 2). In the RTSA with VSP group, one patient showed heterotopic ossifications at radiographic imaging and another patient experienced tingling in the hand after surgery. No complications were observed in the RTSA without VSP group. This revealed no significant difference in complication rate between both groups. The PROMS for more than 1 year follow-up all showed no significant differences between both groups. The mean operating time for RTSA with VSP group is reduced with 18 minutes providing a significant difference ($p < 0.05$) in favor of the with VSP group.

The Bland-Altman plot of the RTSA with VSP group shows positive and negative values of stem height differences with a mean difference of 2.5 mm. The RTSA without VSP shows only positive values with a mean difference of 14 mm. The t-test showed significant difference ($p < 0.001$) in favour of the RTSA with VSP group.

4 Discussion

The clinical outcome for patients surgically treated for a RTSA with and without VSP show no significant differences for range of motion, complication rate and PROMS, but significant differences are shown in favor of with VSP for operating time and stem height positioning.

A limitation of this study is the small and unequal sample sizes. Although ethical approval was granted for a cohort of 78 patients, only 34 were included with a skewed distribution in this interim analysis due to incomplete follow-up (<1 year) or missing outcome data due to transition in electronic patient file supplier. The lost data was more prominent in the without VSP group. Inclusion of additional patients is ongoing. We expect to include in total 30 patients in RTSA with VSP and 25 patients in RTSA without VSP group. For this interim analysis, the more than 1 year follow-up results of the RTSA with VSP group are compared to results retrieved from two review papers presenting results of 1119 patients [9]and 856 patients [10] with a longer follow-up time of over 2.5 years. ROM, PROMS and complication rates are similar. Note that a direct comparison is difficult, because the prosthesis, follow-up time and surgical techniques were different. So in conclusion, we do expect that better position of the prosthesis stem height would positively influence these outcomes and hope to demonstrate that once the follow-up is finished and the study is completed.

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