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8 Years of Shoulder Navigation, an Intra-Operative Performance Retrospective Study

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Abstract

This study aims to retrospectively evaluate the intra-operative performance of computer-assisted navigation (CAN) total shoulder arthroplasty (TSA) over years, analyzing temporal performance evolution and influencing factors.

1 Introduction

Computer-assisted navigation (CAN) has been utilized for decades in knee[1, 11] and hip[8] arthroplasties, but its application in total shoulder arthroplasty (TSA) is recent. CAN currently supports only the glenoid side, enhancing preoperative 3D planning by providing real-time intraoperative guidance to improve implant positioning. It offers significant benefits, such as increased accuracy in glenoid component placement and better correction of deformities, reducing risks of implant failure[3, 2, 5, 12]. Studies indicate improved outcomes with CAN compared to non-navigated procedures[16, 6], with no additional complications[9]. However, its impact on operative time remains debated, with inconsistent findings on whether CAN extends[13, 7, 10] or shortens surgeries[15, 14, 4]. Surgeon performance with CAN and factors influencing it remain underexplored. This study retrospectively evaluates registration and navigation times using a single CAN system over eight years, analyzing performance variations in anatomic (aTSA) and reverse (rTSA) procedures based on operator profiles and several criteria such as native anatomic measurements, implant type or workflow.

2 Material and Methods

Prospectively collected records from a single navigation system (Exactech GPS, Blue-Ortho) using the same platform prosthesis (Equinoxe; Exactech, Gainesville, FL, USA) were retrospectively identified. Initially, all TSA cases performed worldwide using this CAN system since its inception in 2016 through 2024 were included. The following exclusion criteria were then applied:

- Reports involving cadaveric studies;
- Reports in which different cases are loaded one after the other (misuse);
- Reports with registration process restarted after navigation steps (misuse);
- Reports with registration process longer than 20 minutes (outliers);
- Reports with navigation phase longer than 70 minutes (outliers).

This database only hosts de-identified data. A surgeon profile was calculated based on the number of cases performed per sliding year (from date to date), and were divided into three operator profiles:

- Less than 10 cases: Low volume
- From 10 to 50: Medium volume
- More than 50: High volume

Two performances were computed, in minutes, for all cases:

- Registration time: from the first acquisition to the exit of the registration check step. In between, a set of acquisitions recorded areas around the glenoid and the coracoid process. The registration steps are the same for aTSA and rTSA;
- Navigation time: from the entry point navigation until the exit of the last navigated step. The navigated steps are: (1) the entry point, (2) reaming, (3) center hole drilling, (3) peripheral hole drilling (only aTSA) or (3) screws lengths and directions (from 1 to 6 screws) (only rTSA) and (4) implant insertion 17.

These performance times were also then stratified based on procedure type (aTSA or rTSA). And, separately for aTSA and rTSA procedures, the impact of the following factors was investigated:

- The native retroversion (less or greater to 20°);
- The native inclination (inf. or sup.);
- The implant type (augmented or not);
- The surgeon profile;

2.1 Statistical analyses

Data normality was tested using Shapiro-Wilk test. Equality of variances was tested using the Levene's test. If the data exhibited normality with equal variances, the standard Student's t-test was applied. For normally distributed data with unequal variances, Welch's t-test was utilized. In cases where the data did not meet normality assumptions, the non-parametric Mann-Whitney U test was employed. Significance was set at the 5% level for all tests. Statistical analysis were performed using the Python SciPi v1.11.4 library 18.

	Retroversion < 20°		**Retroversion > 20°**		**p-value**
	Mean±SD	Median	Mean±SD	Median	Mann-Whitney
aTSA	N=6444		N=1264		
Registration (min)	3:19±2:30	2:28	3:43±2:45	2:45	p<0.001
Navigation (min)	9:37±7:09	7:26	12:08±8:17	9:49	p<0.001
rTSA	N=27983		N=4274		
Registration (min)	3:25±2:45	2:31	3:35±2:45	2:39	p<0.001
Navigation (min)	15:07±8:59	13:03	19:26±11:30	16:28	p<0.001
	Inclination < 0°		**Inclination > 0°**		**p-value**
	Mean±SD	Median	Mean±SD	Median	Mann-Whitney
aTSA	N=4301		N=3407		
Registration (min)	3:26±2:34	2:34	3:18±2:31	2:28	p=0.002
Navigation (min)	10:30±7:46	8:09	9:26±6:52	7:24	p<0.001
rTSA	N=11369		N=20885		
Registration (min)	3:31±2:48	2:35	3:24±2:43	2:31	p<0.001
Navigation (min)	16:17±10:04	13:51	15:21±9:07	13:15	p<0.001
	Augmented		**Non Augmented**		**p-value**
	Mean±SD	Median	Mean±SD	Median	Mann-Whitney
aTSA	N=5022		N=2728		
Registration (min)	3:29±2:39	2:35	3:11±2:20	2:24	p<0.001
Navigation (min)	10:44±7:50	8:25	8:42±6:18	6:51	p<0.001
rTSA	N=22335		N=10032		
Registration (min)	3:23±2:44	2:30	3:34±2:48	2:38	p<0.001
Navigation (min)	15:35±9:15	13:27	15:57±10:00	13:29	p=0.34

Table 1: Influence of the Glenoid Native Measurments or Implant Type (Augmented or not) on the Performances.

3 Results

In total, 40,117 cases, performed by 1248 surgeons were included, comprising 7750 aTSA and 32,367 rTSA. Mean registration time was 3:26±2:43 minutes and mean navigation time was 14:36±9:24 minutes.

Table 1 display collected results.

For both aTSA and rTSA, native retroversion of the glenoid greater than 20° slowed the registration time and the navigation time.

For both aTSA and rTSA, native glenoid inferior inclination was associated with prolonged registration time and navigation time.

For aTSA, use of the augmented implant slowed both registration and navigation times. For rTSA, on the contrary, use of the augmented implant slightly accelerated registration but had no impact on navigation.

Stratifying cases by surgeon volume 9002 cases were performed by low volume surgeons, 16687 by medium volume and 14428 by high volume.

Regarding the impact of surgeon profile on the performance, for aTSA, during the registration phase, high volume surgeons are 30s faster than medium volume and 2:16min faster than low volume, while medium volume surgeons are 1:45min faster than low volume. For navigation, high volume surgeons are 1:57min faster than medium volume and 5:00min faster than low volume. Medium volume surgeons are 3:02min faster than low volume. All differences were significant (p¡0.001). See Figure 1.

For rTSA, during the registration phase, high volume surgeons were 39s faster than medium volume and 2:32min faster than low volume, while medium volume were 1:52min faster than low volume. For navigation, high volume surgeon were 4:27min faster than medium volume and 11:20min faster than low volume. Medium volume surgeons were 6:53min faster than low volume. All the differences were significant (p¡0.001).

Over the years, from 2017 to 2024, all surgeons included, registration time decreased continuously from 4:30min to 2:36min for aTSA and from 4:46min to 2:59min for rTSA. Navigation time lengthened from 7:52min to 10:11min for aTSA but shortened from 18:04min to 14:31min for rTSA. These trends were shared by all surgeon volume profiles.

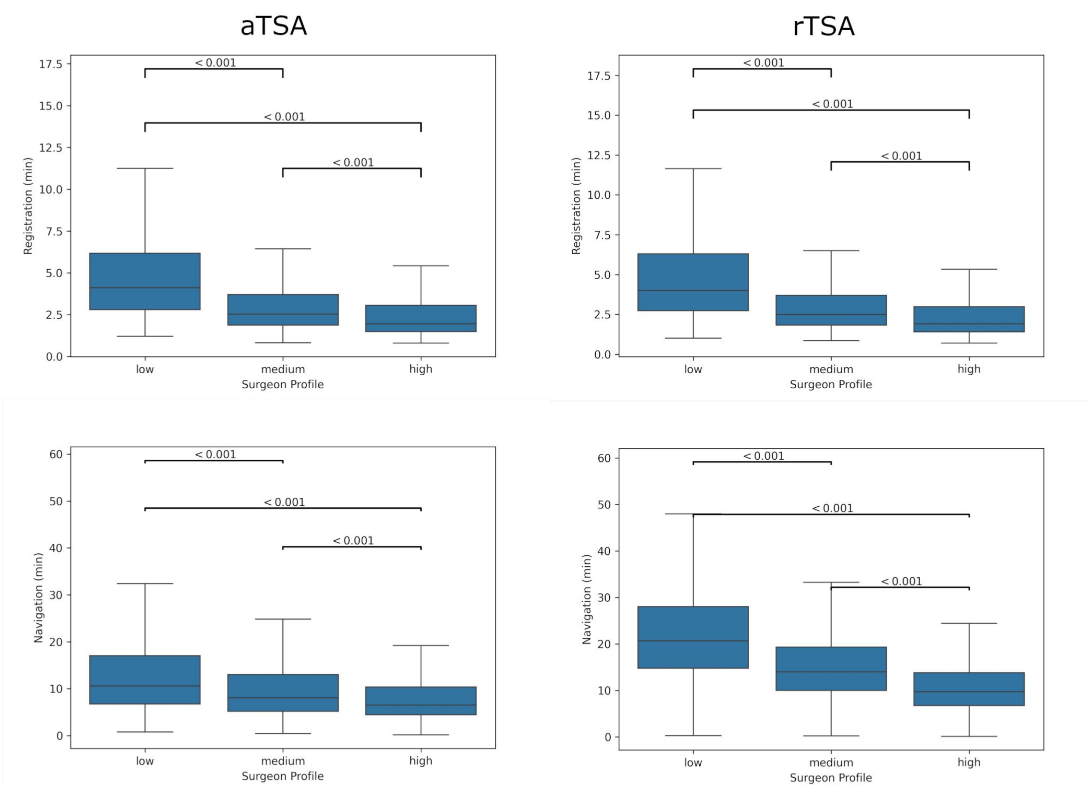

Figure 1: Intra-operative performance by surgeon profile.

4 Discussion and conclusion

This study of over 40,000 navigated TSA cases on a single CAN system investigated the factors influencing the temporal performance of the intra-operative workflow associated with using the CAN system and the evolution of these performances. Most notably, for both aTSA and rTSA, glenoids with high native retroversion or inferior inclination had longer navigation phases. Navigating augmented implants took longer for aTSA but not for rTSA. Finally, although a higher volume of cases performed by year increases operators' performance, all surgeons gained in efficiency over the years, even low-volume profiles.

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