Evaluating an approach to improve operating theatre efficiency with the use of a robotic assistant in total knee arthroplasty.

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Key Findings

1. The ROSA Efficient Care Program improved operating theatre times and reduced overall wheels-in to wheels-out time from a median of 124 (IQR 111 – 143) to 97 (IQR 86 – 114) minutes at final follow-up.
2. Reduction in total OR time increased the number of raTKA cases able to be performed each day from a median of 2 (1 – 3) cases/day to 3 (2 – 4).
3. First case on time starts increased from 41.7% to 87.1% in final follow-up.

Introduction

Every minute in the operating theatre matters. The true cost per minute in theatre has ranged in the literature from USD 16 per minute, not including professional fees, soft goods, or implants to an estimated total cost of approximately USD 37 per minute[1,2]. Due to longer operative times, supplies, and personnel time, robotic-assisted total knee arthroplasty (raTKA) has been reported to cost more than conventional TKA[3]. Despite an abundance of literature on methods to improve operating theatre efficiencies, methods to optimize the workflow in the robotic orthopaedic theatre is a relatively novel process, requiring continuing workflow evaluations[4,5]. This is especially true when new technologies are adopted and learning curves are to be accounted for. The learning curves for raTKA are consistent across platforms and have focused primarily on operative times[6-12]. Most studies report only on the initial learning curve when the surgeon and staff begin to demonstrate confidence in the system and cumulative times begin to drop with inflexion points ranging from five to 40 cases. Despite these relatively low inflexion points, the proficiency phase of learning is often extended with decreases in surgical times continuing beyond six months, or up to 71 cases [13-15]. This may be attributed to improvements in workflows and more familiarity with the system by the entire team. Regardless, the evidence surrounding the adoption of robotics in knee arthroplasty is fraught with concerns of decreased operating theatre efficiency[16,17].

Addressing this concern, Loomans et al.[17] recently performed a retrospective review of 432 consecutive cases (198 navigated total knee arthroplasty [nTKA], and 234 raTKA). Compared to nTKA, the theatre times and instrumentation were less with raTKA. A recent study by Sanchez et al.[18] used the Lean Six Sigma methodology to improve theatre turnover times in bariatric and thoracic surgery and concluded that simplifying steps and performing them in parallel resulted in more efficient turnover times. They also noted that the success of their quality improvement initiative was due, in part, to a committed and active surgical team. These findings suggest that raTKA operating theatre efficiency may also be improved upon.

To better address the initial inefficiencies of robotic adoption at one institution, a quality improvement initiative was adopted from an established program that was developed to evaluate these inefficiencies using Lean Six Sigma methodology (ROSA® Efficient Care)[19]. The initiative was developed to optimize parallel working and accelerate intra-operative efficiencies aiming to achieve time-neutral or faster procedures compared to a non-robotic standard. The program helps the surgical team visualize the workflow and carefully coordinate multidisciplinary tasks with the hope of leading to higher predictability. It also facilitates better planning with the potential to reduce process time and increase operating theatre utilization in raTKA.

The primary objective of this case study was to present the ability of this program to affect theatre times (wheels-in to wheels-out) during implementation and follow-up at a regional public hospital. Additionally, we sought to evaluate the number of robotic cases that occurred per day during the implementation and follow-up phases. Finally, we evaluated a metric for first-case on-time starts (FCOTS).

Methods

This is a secondary analysis of data collected for the primary reason of understanding and improving operative theatre efficiencies following the adoption of raTKA at a single institution. The data was fully anonymized regarding both the surgeons performing the procedures and the patients undergoing raTKA. No patient-specific information was reviewed; thus, an ethics review was not required. A cut-guide positioning robotic stereotaxic instrumentation system for total knee arthroplasty (ROSA® Knee System, Montreal, Quebec, Canada) was introduced into the hospital in 2020. Included in the adoption of this robotic system was access to a quality improvement program (ROSA Efficient Care, Zimmer Biomet) that focused on improving the overall theatre efficiency from wheels-in to wheels-out. The program was developed in 2021 and consists of a quantitative-focused analysis to evaluate bottlenecks and recommendations for improvement. The quality improvement program consists of three phases: group 1) a diagnostic phase, group 2) an implementation phase, and group 3) a follow-up phase to determine if the changes were sustainable.

Diagnostic data were obtained from a consecutive series of 334 robotic cases performed from June 2021 to June 2022 before the implementation phase of the program and after the suspected learning curve of robotic assistance. During the diagnostic phase, a pre-workshop was completed to define the scope and goals of the interdisciplinary team. After these were defined, a standardized qualitative analysis was performed to evaluate theatre data from procedures performed before the implementation of the efficiency program. The scope and goals were then determined based on a focused analysis with quantitative data to evaluate areas of bottlenecks and a means to reduce them. Between the diagnostic phase and the implementation phase, no other quality initiatives for time efficiency were performed at the institution. Pre-workshops for this initiative began in February of 2022. The first 46 cases that were performed upon completion of the workshops (August 2022) during the implementation phase (August to October 2022) were compared to a subsequent follow-up phase (n=96, January to March 2023) that occurred approximately four months following the implementation phase to assess if gains in efficiency were maintained or improved upon. Fourteen cases with missing data were excluded from the final analysis due to missing wheels-in and wheels-out times.

A checklist was used to evaluate the following: surgery list (finalized one week prior), surgeries scheduled on dedicated days and theatres, consistency with the robotic list and number of cases, and the number of changes from the initial list to the final (24 hours before the procedure) list are limited to <20%. Regarding the dedicated theatre, the team consisted of the surgeon, surgical assistant, scrub nurse, circulating nurse, a robotic nurse, and the anaesthetic team, all of whom were specially trained to improve efficiency in their role. Most implants (~75%) consisted of the Vanguard® Knee System (Zimmer Biomet, Warsaw, IN, USA) with the remaining including the Persona® Knee System (~25%, Zimmer Biomet, Warsaw, IN, USA). All cases were performed inpatient as elective procedures. Time stamps of the following points were captured manually: wheels in the theatre, incision cut time, incision close time, and wheels out of the theatre. The appropriate workshops were then recommended based on these findings, amongst others. FCOTS was standardized so that cases with the initial incision starting at or before 8:30 a.m. were considered to have started on time.

For implementation, a preliminary workshop was completed followed by two follow-up meetings. The workshop followed Lean Six Sigma methodology starting with the question "How do you do it now?" and finishing with "How do you want to do it tomorrow?". This allowed the team to identify obstacles, redundancies, and waste in the process, address these issues, and create a new, more efficient process.

Visual representation is provided in a scatter plot across time with locally weighted scatter plot smoothing as a best-fit line. A Shapiro-Wilk test demonstrated that the data deviated significantly from a normal distribution. Thus, pairwise comparisons were performed using a Wilcoxon Rank Sum Test. Hommel's Procedure was used to adjust for multiplicity. Data are reported as median and interquartile ranges or frequency (percent). FCOTS was evaluated using a Fisher's Exact Test between groups using a 2x3 matrix. Significance was assessed at $p<0.05$. Analyses were performed using STATA v. 12.1 (College Station, TX, USA).

Results

Total theatre times decreased from a median 124 minutes (IQR 111 – 143) to 106 minutes (IQR 95 – 118) in the implementation phase and down to 97 minutes (IQR 86 – 114) in the follow-up phase (**Table 1**). When visualizing theatre time from wheels-in to wheels-out over all the cases, the line of best fit demonstrates a negative relationship between time and the number of cases (**Figure 1**).

Figure 1
Scatter plot of wheels-in to wheels-out times across cases, with the line of best fit (locally weighted scatter plot smoothing).

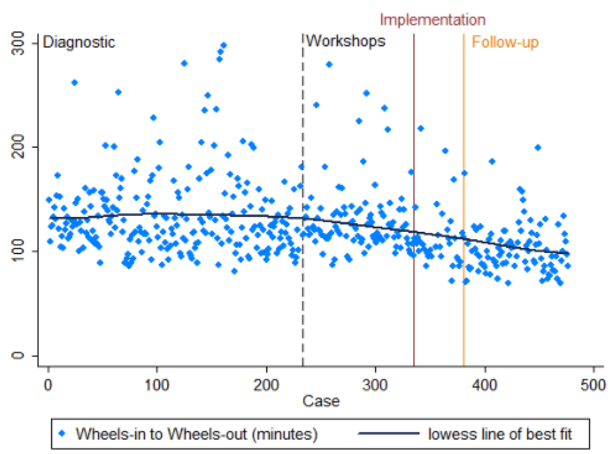
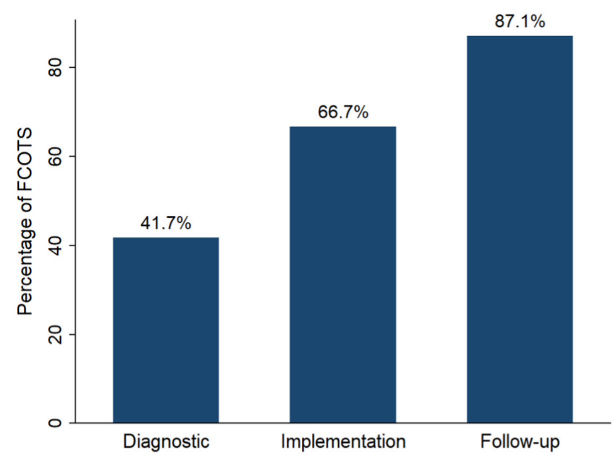


Figure 2
Bar graph demonstrating the difference in first case on time starts between groups.



Time	Diagnostic (group 1)	Implementation (group 2)	Follow-up (group 3)	Pairwise Comparison: P value
Wheels-in – Wheels-out	124 (111 – 143)	106 (95 – 118)	97 (86 – 114)	Group 1-2: p<0.001* Group 2-3: p=0.033* adjusted Group 1-3: p<0.001*
Wheels in – disinfection	N/A	3 (2-5)	2 (2-4)	Group 2-3: p=0.0271* N/A
Wheels in – incision	27.5 (22 – 35)	11 (9 – 14)	11 (8.5 – 13)	Group 1-2: p<0.001* Group 2-3: p=0.501 adjusted Group 1-3: p<0.001*
Wheels in – close	112 (99 – 132)	97 (87 – 107)	88 (75 – 101)	Group 1-2: p<0.001* Group 2-3: p=0.013* adjusted Group 1-3: p<0.001*
Incision – close	N/A	85 (79 – 95)	75.5 (66 – 90)	Group 2-3: p=0.006* N/A

N/A: not appropriate, *Statistically significant

Table 1
Pairwise comparisons of operating theatre times, presented as median (Interquartile range) for time in minutes.

Discussion and Conclusion

DeCook and Statton have described the need for "radical time transparency" for operational excellence when achieving improved operating theatre efficiencies[20]. Our data demonstrated that a quality improvement program using specific time stamps resulted in significant time savings from wheels-in to wheels-out in raTKA. There was a reduction of roughly 30 minutes from the diagnostics phase through the follow-up phase for the time the patient was in the theatre. This improved efficiency resulted in more raTKA cases being completed per day, from a median of two to three cases at the time of the follow-up. Since then, proficiency has continued to improve, and the site is consistently performing four raTKA cases per day. Additionally, FCOTS improved from roughly 42% of incisions starting prior to or at 8:30 AM to 87%.

The ability to identify and address bottlenecks in the operating theatre is essential for determining solutions to improve performance[21]. One of these indicators is the raw count of patient time in theatre[21], which has been shown to be higher in robotic vs. conventional TKA[22]. Using a CT-based robotic system, Fang et al.[22] reported total operating room times of approximately 145 ± 17 minutes for raTKA and 131 ± 23 minutes for conventional TKA. Zak et al.[16] reported statistically and clinically increased total theatre times in technology-assisted procedures when looking at the effect of computer-assisted surgery and robotic assistance in TKA. Similarly, Cotter et al.[23] reported an increased total theatre time of roughly 13 minutes in robotic cases. Meghpara et al.[24] reported only an eight-minute increase in total theatre time using a CT-based robotic system. In an ambulatory surgery center (ASC), Eason et al.[25] reported that raTKA cases took an additional seven minutes on average compared to conventional and concluded that robotics could safely be incorporated into the ASC. In contrast, Masilamani et al.[26] have recently shown improvements below conventional case times for simultaneous bilateral raTKA. The differences in these studies suggest that robotic times are not stagnant and may be improved upon with an efficiency-based program to meet or be less than conventional case times. Further, Shatrov et al.[27] have suggested that reduced operating time can be realized with improved efficiency over time. Our data agrees, showing proof of concept that this is achievable.

When evaluating the benefits of an efficiency program on FCOTS, Chapman et al.[28] have reported a significant improvement in both FCOTS and the last cases ending on time. They suggest that cost savings can be achieved through initiatives that focus on FCOTS. During their study, they reported the frequency of FCOTS improving from 76.1% to 86.6% ($p<0.01$) from their pre- to post-intervention analysis. Our data demonstrated significant improvements from a frequency of approximately 42% of cases starting on time in the diagnostic group to 87% in the follow-up group. Further research is needed to determine if the FCOTS seen at this institution were also correlated with last cases ending on time. Regardless, the ability to add additional robotic cases on the same day suggests improved efficiency overall, including starting the first cases on time.

In conclusion, a dedicated staff and compliance with a quality improvement program implemented at the time of robotic assistance in TKA can reduce total operating theatre times and improve the efficiency of the procedure overall. Additional research is needed to determine the point of plateau or final proficiency and to document if improvements can continue to be seen. Future studies are needed to compare total theatre times in raTKA with conventional manual TKA, as well as to assess other efficiency parameters.

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