Journal of Robotic Surgery (2024) 18:86
https://doi.org/10.1007/s11701-024-01823-y

RESEARCH

Analysis of robot-specific operative time and surgical team anxiety level and its effect on alignment during robot-assisted TKA

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Received: 7 December 2023 / Accepted: 10 January 2024

Abstract

Adapting to robotic-assisted (RA) total knee arthroplasty (TKA) is hindered by the surgeon's fear of extra time. The main purpose of this study was to determine the robot's operative time, and the secondary goals were to assess the surgical team's anxiety, implant location and size, and limb alignment. From February to April 2022, 40 participants participated in prospective research. The study included primary Cuvis joint active RA-TKA patients for end-stage arthritis, but conversion of unicompartmental knee arthroplasty to TKA, and patients with prior knee surgery were excluded. The active RA-TKA surgical time included surgeon-dependent and surgeon-independent/active robot time. The surgeon's anxiety was measured using the state-trait anxiety inventory (STAI). The implant size/position and limb alignment were checked by post-operative weight-bearing lateral, anteroposterior, and full-length scanograms. Operative time specifically related to active RA-TKA was higher in the first 10 cases as against 10–20, 20–30 and 30–40 cases which was observed to lower from cohort 2. A similar trend was observed for the surgical team's anxiety levels which seem to lower from cohort 2 (case 10–20). Cumulative experience of active RA-TKA showed no effect on the precision of implant alignment/ size, limb alignment and complications. The study showed progressive improvement in the surgical anxiety scores and reduction in operating time indicating the proficiency gained by the surgical team. Further no learning curve was involved in achieving the implant positioning and sizing, limb alignment with the absence of complications.

Keywords Learning curve · Robotic-assisted total knee arthroplasty · Surgical team anxiety

Abbreviations

TKA	Total knee arthroplasty
RA-TKA	Robotic-assisted total knee arthroplasty

Introduction

Total Knee Arthroplasty (TKA) is a standard established procedure for patients with end stage (grade 4) arthritis [1–4]. Despite its success, literature reports dissatisfaction in about 20% of TKA patients [5–11]. The use of computer and robotic-assisted (RA) -TKA is on the rise. The utilization of RA-TKA facilitates precise bone excision and enables correct preoperative prediction of femur and tibial implant sizes [12, 13]. This technology also aids in obtaining the proper implant and limb alignment. Robotic-assisted TKA in comparison to traditional TKA has also been shown to reduce the incidences of iatrogenic bone and periarticular soft tissue injury [12, 14, 15]. The aforementioned reasons help in achieving higher levels of post-surgical patient satisfaction and desired clinical results. It also helps in improving the long-term implant survivorship [15–17].

The most important inhibition in the arthroplasty surgeon's mind about adapting the RA technology for performing TKA is the learning curve associated and consequently the extra time he/she going to spend doing the RA-TKA procedure. A few studies are available about the learning curve estimation, about the use of semiautomatic robot in performing RA-TKA [18, 19]. Cuvis joint robotic system (Curexo, Korea, supported by Meril Life Sciences, Pvt. Ltd, India) is fully automatic robotic TKA system. It is US-FDA approved and European CE mark, and Ministry of Food and

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Published online: 22 February 2024

Drug Safety of the Republic of Korea approved joint surgical robot [20]. It uses a pre-operative 3-dimensional (3-D) computerized tomography (CT) scan to create individual patient-specific bone model. The surgeon along with the software engineer plans the TKA procedure pre-operatively choosing accurate implant size/ position and limb alignment (Hip-Knee-Ankle axis) of 180°. In this system, after registration and confirmation of femur and tibia bony points, the fully automatic robot is attached to the patient and all femur and tibia cuts are done with the help of bone burr which mills the bone. To the best of our knowledge, no research has been conducted on the estimation of the learning curve for the fully autonomous Cuvis Joint robot.

The primary goal of the present study is to investigate the robot-specific operative time associated with RA-TKA using a fully automated Cuvis Joint robot. The secondary aim of the study was to assess the anxiety levels of the surgical team, the accuracy of the implant size/ position and alignment of the limb and to study post-operative complications if any.

Methods

This is a prospective, single-center study that included 40 patients undergoing fully automatic RA-TKA. The surgical team included experienced surgeons who regularly performed conventional TKA and were provided saw-bone training utilizing RA-TKA. The inclusion criterion was patients with symptomatic end stage arthritis requiring RA-TKA while the exclusion criteria were conversion of unicompartmental arthroplasty to TKA and conversion of high tibial osteotomy to TKA. The study had an ethics committee approval for the participating institute. Written informed consent was obtained from all patients enrolled for the study. All 40 patients were implanted with posterior stabilized high flexion Freedom total knee system (MAXX Orthopedics, Inc., Plymouth Meeting, Pennsylvania) utilizing a fully automatic Cuvis Joint robot. Routine pre-operative anteroposterior and lateral knee radiographs, hip-knee-ankle (HKA) scanograms along with pre-operative CT scans of the operated leg was performed in all the patients. The axial plane was utilized to conduct scans of the leg in the regions of hip, knee and ankle and the images were then transferred in the. jpg format. The pre-operative planning process relied on the mechanical alignment approach rather than the kinematic alignment concept. The desired alignment of the limb was neutral with an HKA axis of 180°. The surgical team along with the system software engineer did the surgical planning choosing the best fit femur and tibia implant achieving HKA angle of 180°. Particular attention was given to make sure that there was no femur implant overhang or notching and posterior condylar offset ratio is restored. As regards the tibial component, the native posterior tibial slope was restored making sure that there is no mediolateral or anteroposterior overhang. A mechanical alignment philosophy was used in planning the limb alignment. The HKA angle of 178° to 182° was deemed to be acceptable alignment. The surgical time specifically related to the active RA-TKA was defined as surgeon-dependent time (time for the insertion of the femoral and tibial registration pins + time for the bony registration) and surgeon-independent/ active robot-related time (time taken for docking the active robot to the patient + time taken for bone resection by bone milling performed by an active robot). The anxiety level of the surgical team (comprising 2 assistant orthopaedic surgeons headed by one senior surgeon) was assessed utilizing the Spielberger State-Trait Anxiety Inventory (STAI) questionnaire, a well-established and validated subjective assessment tool. This approach measures an individual's stress levels by considering the specific qualities that emerge from the clinical situation. The questionnaire designed by Marteau et al. consists of six items and is a 4-point-based system. The total scores on this questionnaire range from 6 to 24 [21]. Scores are directly proportional to stress levels; higher level stress is indicated by higher scores. Prior to the commencement of the surgery, all members of the surgical team took the STAI assessment. Accuracy of the implant size/ position and alignment of the limb was evaluated by the post-operative weight-bearing lateral and anteroposterior radiographs and full-length scanograms. An external observer, independent of the surgical team, evaluated the surgery duration, the surgeon's anxiety levels, and the precision of implant size and positioning, accuracy of limb alignment, as well as the occurrence of any post-surgical complications. Statistical analysis was carried out by student's *t*-test for comparison of means and p-value < 0.05 was considered statistically significant (Fig. 1).

Results

For convenience, the patients were grouped into 4 cohorts of 1–10, 11–20, 21–30 and 31–40. The patient's baseline characteristics are shown in Table 1 and there was no significant difference in the pre-operative patient's attributes in all four cohorts.

The robot-specific operative time (mean ± standard deviation) for the four patient cohorts was: cases 1–10: 27.3 ± 3.83, cases 11–20: 24.8 ± 4.05, cases 22–30: 24.9 ± 3.30 and cases 31–40: 25.5 ± 2.42, respectively (Table 2).

The operative cases 1–10 took longer time than 11–20, 21–30 and 31–40 cases, p-value 0.0170, statistically significant. From cohort 2, there was no statistically significant difference as regards the operative time between cohort 2,

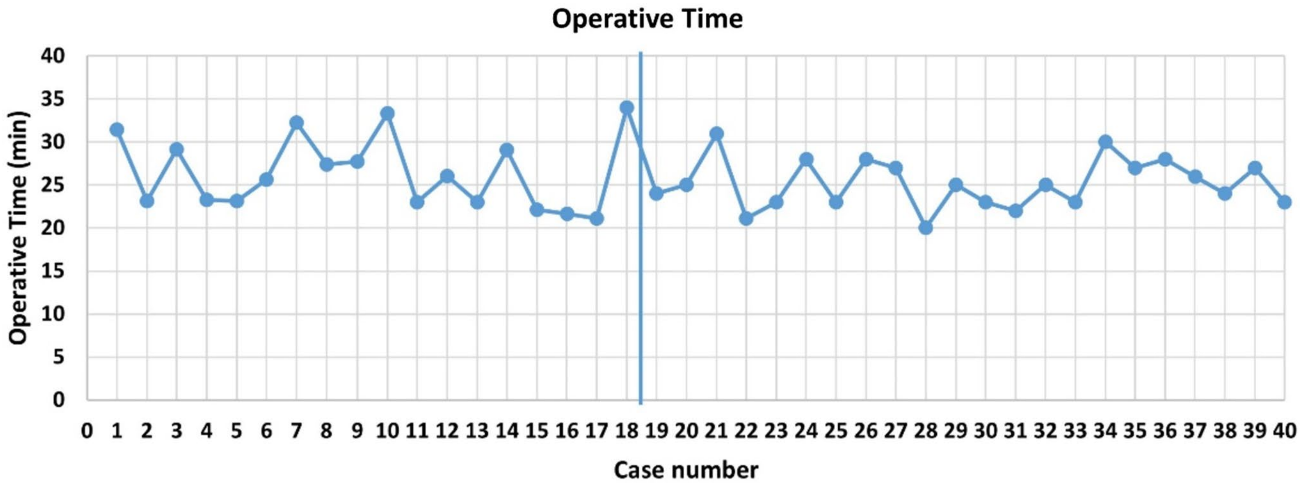

Fig. 1 provides observation where beyond case 18 i.e., cohort 2 operative time seems to be lower

Table 1 Comparison of preoperative patient characteristics between all four patient group cohorts

Cohort (case numbers)	1 (0–10)	2 (10–20)	3 (20–30)	4 (30–40)
Number of patients (*n*)	10	10	10	10
Mean age (years)	67.3 ± 15.4	66.7 ± 15.9	66.4 ± 14.8	67.1 ± 15.1
Mean BMI (kg/m^2)	28.4 ± 4.5	27.5 ± 5.3	27.7 ± 5.4	28.1 ± 4.7
Mean preoperative VAS score	7.2 ± 2.1	7.6 ± 1.9	7.3 ± 1.9	7.2 ± 2.4
Pre-operative ROM	95.8 ± 19.3	95.4 ± 18.2	94.5 ± 19.7	94.9 ± 19.5
Pre-operative degree of deformity	8.6 ± 2.5	9.7 ± 3.1	9.4 ± 2.9	8.9 ± 2.4

BMI body mass index, *VAS* Visual analogue scale, *ROM* Range of Motion

Table 2 Comparison of surgical time (surgeon dependent + surgeon independent) specifically related to the active robotic-assisted TKA

Serial case number	Time for registration + Time for docking and bone resection	*p* value
1–10	27.3 ± 3.83	–
10–20	24.8 ± 4.05	0.0170
20–30	24.9 ± 3.30	0.9280
30–40	25.5 ± 2.42	0.4282

3 and 4 (p-value 0.9280 for cohort 2 -3 and p-value 0.4282 for cohort 3–4) (Table 3).

Assessment of the anxiety levels (Fig. 2) revealed highest STAI scoring in cohort 1 (cases 1–10) than cohort 2 (cases 11–20) p-value 0.0003, reducing in cohort 3 (cases 21–30) p-value < 0.0001 (cohort 2 vs. cohort 3) and lowest with cohort 4 with p-value 0.0233 when compared to cohort 3 (Table 4).

Analysis of the post-operative radiographs revealed no oversizing or undersizing of the femur or tibia implant. There were no outliers on the post-operative scanograms as regards the HKA angle (acceptable range 180° ± 2°). One patient in cohort 3 developed a wound dehiscence which was managed by debridement of wound edges and secondary suturing.

Discussion

The main findings of our study are that robot-specific operative times were longer in the first 10 cases. The operative cases 1–10 took longer time than 11–20, 21–30 and 31–40 cases. Beyond case no 18, there was no statistically significant difference as regards the operative time between cohort 2, 3 and 4. This indicates an inflection point of the initial 18 cases (cohort 2) where the surgeon progresses from the learning to the proficiency phase of the active RA-TKA procedure. The surgical team anxiety level also progressively decreased from cohort 1 to 4, indicating surgical team becoming familiar with the adaptation of the active RA technology and thereby getting accustomed to the technique of active RA-TKA. As regards the secondary objective the cumulative active RA-TKA experience did not affect the accuracy of the implant size and positioning, achieved acceptable limb alignment (178–182°) with the absence of surgical complications.

Table 3 Case-wise surgical time specifically related to the active robotic-assisted TKA

Sr. no.	Side	Time taken for registration (minutes)	Time taken for docking and bone resection (minutes)	Total time taken (minutes)	Planned femur size	Actual femur size	Planned tibia size	Actual tibia size
1	Right	0:07:09	0:24:16	0:31:25	D	D	2	2
2	Left	0:06:01	0:17:08	0:23:09	C	C	1	1
3	Right	0:08:09	0:21:00	0:29:09	C	C	2	2
4	Left	0:09:05	0:14:10	0:23:15	C	C	2	2
5	Right	0:06:04	0:17:04	0:23:08	C	C	2	2
6	Left	0:10:01	0:15:38	0:25:39	B	B	1	1
7	Right	0:08:01	0:24:15	0:32:16	C	C	1	1
8	Right	0:07:08	0:20:14	0:27:22	C	C	2	2
9	Right	0:08:01	0:19:41	0:27:42	F	F	5	5
10	Left	0:08:20	0:25:00	0:33:20	F	F	5	6
11	Right	0:06:00	0:17:00	0:23:00	B	B	1	1
12	Left	0:06:01	0:20:00	0:26:01	B	B	1	1
13	Left	0:07:00	0:16:00	0:23:00	C	C	2	2
14	Right	0:06:04	0:23:00	0:29:04	C	C	1	1
15	Left	0:06:04	0:16:04	0:22:08	B	B	1	1
16	Left	0:06:00	0:15:38	0:21:38	B	B	1	1
17	Right	0:05:01	0:16:04	0:21:05	B	B	1	1
18	Right	0:07:00	0:27:00	0:34:00	C	C	2	2
19	Right	0:05:01	0:19:00	0:24:01	B	B	2	2
20	Right	0:08:01	0:17:00	0:25:01	C	C	2	2
21	Left	0:08:00	0:23:00	0:31:00	C	C	3	3
22	Left	0:05:06	0:16:00	0:21:06	D	D	3	3
23	Right	0:06:00	0:17:00	0:23:00	D	D	4	4
24	Left	0:07:00	0:21:00	0:28:00	D	D	3	3
25	Right	0:05:01	0:18:00	0:23:01	C	C	3	3
26	L eft	0:07:00	0:21:00	0:28:00	E	E	4	4
27	Right	0:06:00	0:21:00	0:27:00	E	E	4	4
28	Right	0:05:00	0:15:00	0:20:00	B	B	1	1
29	Right	0:10:00	0:15:00	0:25:00	B	B	2	2
30	Left	0:07:00	0:16:00	0:23:00	C	C	2	2
31	Right	0:06:00	0:16:00	0:22:00	D	D	3	3
32	Left	0:08:00	0:17:00	0:25:00	B	B	2	2
33	Right	0:06:00	0:17:00	0:23:00	B	B	2	2
34	Left	0:08:00	0:22:00	0:30:00	D	D	3	3
35	Right	0:06:00	0:21:00	0:27:00	E	E	3	3
36	Left	0:08:00	0:20:00	0:28:00	B	B	1	1
37	Right	0:10:00	0:16:00	0:26:00	B	B	1	1
38	left	0:07:00	0:17:00	0:24:00	B	B	1	1
39	Right	0:08:00	0:19:00	0:27:00	B	B	1	1
40	Left	0:07:00	0:16:00	0:23:00	B	B	2	2

Determination of a learning curve for a particular surgical technique is extremely important [22]. Learning curve indicates the time taken to adopt a new surgical technique and the number of repetitions to be done by the surgeon to become comfortable with a particular technology/ surgical procedure. Assessment of the learning curve also helps in analyzing the complications/ difficulties faced by the surgical team during the period of learning [23, 24]. It also helps the operating surgeon to do his/her own risk vs. benefit analysis to decide about the use of a particular technology/procedure in the surgical practice. Orthopedic surgeons have always been inclined towards fast adoption of

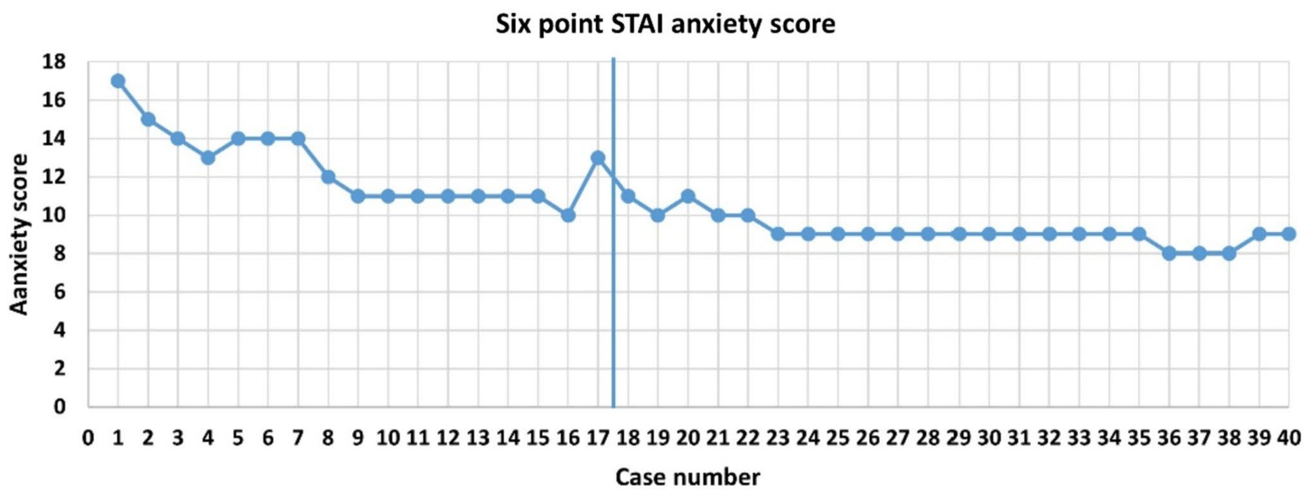

Fig. 2 Represents the case-wise presentation of the anxiety level of the surgeons specifically related to the active robotic-assisted TKA

Table 4 Comparison of the surgical team's anxiety levels according to the six-item questionnaire score

Serial case number	Total score	*p* value
1–10	13.5 ± 1.84	–
10–20	10.8 ± 0.42	0.0003
20–30	9.2 ± 0.42	< 0.0001
30–40	8.7 ± 0.48	0.0233

the new emerging surgical technology [25]. Between 2008 and 2015 there was a threefold increase in the adoption of computer-assisted technology [26]. Researchers, biomedical engineers, and orthopedic surgeons have continually looked for methods to improve patient-oriented outcomes measures. This is necessitated by the fact that approximately 20% of TKA patients are not satisfied with the post-TKA results. The utilization of RA-TKA enables the surgeon to do pre-operative templating and planning, specifically in relation to the sizing and placing of the femur and tibial implants. This includes ensuring precise alignment of the limb with the 180° HKA axis. Robotic-assisted TKA carries out bone resections with sub-millimeter accuracy. The primary source of anxiety and tension for surgeons when considering the implementation of a novel surgical method is the apprehension regarding a potential increase in operative times and decrease in efficiency. Several studies have reported varying learning curves for the Mako, OMNIBotics, and NAVIO robotics systems in the context of RA-TKA [27, 28]. These studies have identified learning curves of 7, 7, and 12 cases for the respective systems [27, 28].

The robot-specific operative time in our study decreased from cohort 2 onwards. This is because the surgical and nursing team got familiar with the steps and workflow of the active RA-TKA procedure. The surgical time specifically related to the active RA-TKA consisted of surgeon-dependent time (time for the insertion of the femoral and tibial registration pins + time taken by surgeon for the bony registration) and surgeon independent/ active robot-related time (time taken for docking the active robot to the patient + time taken for bone resection by bone milling performed by an active robot). In our study, the most significant improvement happened with surgeon-dependent time indicating less time taken by the surgeon for insertion of registration pins and time taken for femur and tibia bony registration. The anatomical bony registration landmarks (femur and tibia) were the same in all the patients. Hence with incremental surgical experience, the surgeon progressively took less time for the bony registration. In relation to the duration of the surgeon's independent and active robot-assisted procedures, which encompasses the time required for docking the active robot to the patient and the time taken for bone resection through active robot-performed bone milling, a moderate enhancement was observed as the surgical and nursing team grew more familiar with the surgical technique workflow. The results of our investigation align with the research conducted by Sodhi et al. [19] and Mahure et al. [29]. In a study conducted by Sodhi et al. it was demonstrated that the learning curve for performing RA-TKA consisted of 20 cases [19]. Conversely, Mahure et al. found that active RA-TKA exhibited a somewhat shorter learning curve ranging from 10 to 20 cases [29].

Higher levels of anxiety and stress observed in the surgical team for the initial 10 RA-TKA cases are revealed in the high scores obtained for the STAI questionnaire. This is significant as elevated mental stress and strain affects the decision-making ability and impairs technical skills thereby resulting in suboptimal operative performance [21]. The findings of our study demonstrated a gradual decrease in surgical anxiety levels throughout cohort 1 to cohort 4, suggesting an increasing level of proficiency within the surgical team in terms of both technical aspects and the overall understanding of the workflow of active RA-TKA. Another important finding of our study is that the initial surgical learning curve and the high surgical team anxiety levels did not affect the secondary outcomes measures. The possible explanation for the same may be certain unique features of the active RA-TKA namely the pre-operative planning carried out on the 3-D CT scan generated bone model, the accurate tracking of the femur and tibia bone resection windows within stereotactic boundaries thereby minimizing the chances of bone resection errors and soft tissue injuries. These unique features might have helped in achieving high accuracy in implant size/ position as well as limb alignment.

Limitations

The primary constraint pertains to the surgical team participating in the study, as they possess prior familiarity with computer-assisted (CAS) TKA. Consequently, it is inappropriate to generalize their surgical time findings to surgical teams lacking exposure to CAS. One notable constraint of this study is being a single center investigation and a small sample size. To advance the current body of knowledge, it is imperative to conduct a multicenter investigation on the utilization of active RA-TKA. A third drawback of the study was the failure to include the additional expenses associated with the utilization of the active RA-TKA technology.

Conclusion

The use of fully automatic active RA-TKA led to increased operative time (specific to robot) as well as increased anxiety level of the surgeon in the first 17 and 18 cases, respectively. The study showed progressive improvement in the surgical anxiety scores and a reduction in the operating time from cohort 2, indicating the proficiency of the surgical team. The initial prolongation of surgical duration and the elevated levels of anxiety experienced by the surgical team did not have a significant impact on the precision of implant size and positioning, limb alignment, and post-surgical complications.

Author contributions SBL contributed to the study conception, data analysis and design. Material preparation, data collection and analysis were performed by RTR, RVS, C.DeS, VS, FSK and SB. The first draft of the manuscript was written by SBL and RTR and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding We confirm that no funding was recieved for this study and the declaration in the eproofing is accurate.

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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