The Learning Curve Associated with Robotic Total Knee Arthroplasty

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Abstract

As with most new surgical technologies, there is an associated learning curve with robotic-assisted total knee arthroplasty (TKA) before surgeons can expect ease of use to be similar to that of manual cases. Therefore, the purpose of this study was to (1) assess robotic-assisted versus manual operative times of two joint reconstructive surgeons separately as well as (2) find an overall learning curve. A total of 240 robotic-assisted TKAs performed by two board-certified surgeons were analyzed. The cases were sequentially grouped into 20 cases and a learning curve was created based on mean operative times. For each surgeon, mean operative times for their first 20 and last 20 robotic-assisted cases were compared with 20 randomly selected manual cases performed by that surgeon as controls prior to the initiation of the robotic-assisted cases. Each of the surgeons first 20 robotic assisted, last 20 robotic assisted, and 20 controls were then combined to create 3 cohorts of 40 cases for analysis. *Surgeon 1*: First and last robotic cohort operative times were 81 and 70 minutes ($p < 0.05$). Mean operative times for the first 20 robotic-assisted cases and manual cases were 81 versus 68 minutes ($p < 0.05$). Mean operative times for the last 20 robotic-assisted cases and manual cases were 70 versus 68 minutes ($p > 0.05$). *Surgeon 2*: First and last robotic cohort operative times were 117 and 98 minutes ($p < 0.05$). Mean operative times for the first 20 robotic-assisted cases and manual cases were 117 versus 95 ($p < 0.05$). Mean operative times for the last 20 robotic-cohort cases and manual cases were 98 versus 95 ($p > 0.05$). A similar trend occurred when the times of two surgeons were combined. The data from this study effectively create a learning curve for the use of robotic-assisted TKA. As both surgeons completed their total cases numbers within similar time frames, these data imply that within a few months, a board-certified orthopaedic joint arthroplasty surgeon should be able to adequately perform robotic TKA without adding any operative times.

Keywords
- robotic-assisted total knee arthroplasty
- total knee arthroplasty
- learning curve

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Optimal implant positioning is a key component for a successful total knee arthroplasty (TKA).[1] Malaligned components can result in increased need for revision surgery, accelerated component wear, and lower patient satisfaction.[1–4] Therefore, recent advances in guidance systems to help orthopaedic surgeons to overcome these obstacles have become a crucial point of investigation. Robotic-assisted TKA devices have shown great surgical potential to be a solution to this problem as many studies have shown the ability for robotic-assisted devices to help achieve better knee alignment over the conventional, manual technique.[5–7] Not only can the robotic-assisted device help achieve better implant alignment but also the device can consistently and accurately reproduce desired results.[8]

Although there are clear potential surgical and clinical advantages to using the robot, some studies have noted robotic-assisted TKA requiring greater operative times.[9,10] Higher operative times require longer anesthesia for the patient and possibly increased operating costs. However, this increased operative time is likely due to a preliminary learning period often associated with implementation of most new surgical technologies.[11] A similar phenomenon was seen in robotic-assisted total hip arthroplasty, as operative times decreased with increased surgeon experience.[12]

Although a study on the learning curve associated with robotic-assisted total hip arthroplasty exists,[12] no such recent study has been performed regarding a learning curve for robotic-assisted TKA. Therefore, the purpose of this study was to assess robotic-assisted versus manual operative times of two joint reconstructive surgeons separately, as well as find overall learning curve.

Methods

Patient Acquisition

A total of 240 robotic-assisted TKA cases performed by two board-certified surgeons were analyzed. Both surgeons were lower extremity fellowship trained and operated at medium-volume nonacademic hospitals, that is, community based, that had programs performing ~500 to 600 lower extremity joint arthroplasties per year. However, these were the first robotic cases performed by these surgeons. The robotic device that was used was Mako System (Stryker, Mahwah, NJ). Manual cases from 3 months prior to the introduction of robotic technology were used as controls. A total of 180 robotic cases were performed by surgeon 1, while 60 robotic cases were performed by surgeon 2. Each case was then sequentially grouped into cohorts of 20 cases per cohort. This yielded nine cohorts for surgeon 1 and three cohorts for surgeon 2. Forming these cohorts effectively created multiple time intervals at which the patients could be compared. A random sample of 20 manual cases performed within 3 months of introduction of robotic technology was selected. Operative times were compared individually for each surgeon, as well as for both surgeons combined.

Operative Times

Operative times were calculated as the time from the opening incision to last closing stitch. For each surgeon, the mean operative times for his first 20 and last 20 robotic-assisted cases were compared with each other and then to 20 randomly selected manual cases that were performed 3 months prior to the introduction of robot. These randomly selected manual cases were performed by that surgeon prior to the initiation of the robotic-assisted cases and were considered controls. Both of the surgeons first 20 robotic assisted, last 20 robotic assisted, and 20 controls were then combined to create three different groups of 40 cases per group for analysis.

Data Analysis

Operative times were collected and stored in Excel document (Microsoft, Redmond, WA). These were grouped into sequential 20 cases for each surgeon. In addition, operative times were combined sequentially into groups of 40. Mean operative times were compared using Student's *t*-tests for significant differences with a *p*-value of < 0.05. All statistical analyses were completed using SPSS version 24 (IBM Corporation, Armonk, NY).

Results

Surgeon 1

Results from surgeon 1 yielded mean operative times of 81, 74, 77, 74, 70, 73, 69, 72, and 70 minutes for each of the nine sequential robot cohorts. These data indicate a significant decrease in mean robotic-assisted TKA operative times from cohort 1 to cohort 9 (81 vs. 70 minutes, $p < 0.05$) (►**Table 1**). In addition, a significant difference was found between the mean operative times for the first robotic-assisted cohort and the manual cohort (81 vs. 68 minutes, $p < 0.05$) (►**Table 2**). However, no significant differences in mean operative times were found between the last robotic-assisted cohort and manual cohort (70 vs. 68 minutes, $p > 0.05$) (►**Table 3**).

Table 1 Surgeon 1 robotic-assisted TKA

	Robotic-assisted cases 1–20 Mean (range)	Robotic-assisted cases 160–180 Mean (range)	*p*-Value
Total (*N*)	20	20	
Time (min)	81 (71–104)	70 (52–121)	<0.05

Abbreviation: TKA, total knee arthroplasty.

Table 2 Surgeon 1 first 20 robotic-assisted TKA versus manual controls

	Robotic-assisted cases 1–20 Mean (range)	20 manual cases Mean (range)	*p*-Value
Total (*N*)	20	20	
Time (min)	81 (71–104)	68 (50–106)	<0.005

Abbreviation: TKA, total knee arthroplasty.

Table 3 Surgeon 1 last 20 robotic-assisted TKA versus manual controls

	Robotic-assisted cases 160–180 Mean (range)	20 manual cases Mean (range)	*p*-Value
Total (*N*)	20	20	
Time (min)	70 (52–121)	68 (50–106)	>0.05

Abbreviation: TKA, total knee arthroplasty.

Table 6 Surgeon 2 last 20 robotic-assisted TKA versus manual controls

	Robotic-assisted cases 40–60 Mean (range)	20 manual cases Mean (range)	*p*-Value
Total (*N*)	20	20	
Time (min)	98 (67–123)	95 (71–142)	>0.05

Abbreviation: TKA, total knee arthroplasty.

Surgeon 2

Results from surgeon 2 yielded mean operative times of 117, 97, and 98 minutes for each of the three sequential cohorts, respectively. There was a significant decrease in mean robotic-assisted TKA operative times from cohort 1 to cohort 3 (117 vs. 98 minutes, $p < 0.005$). Furthermore, a significant difference was found between the mean operative times of the first 20 robotic-assisted cohort cases to 20 manual cohort cases (117 vs. 95 minutes, $p < 0.005$). However, no significant differences were found between the last 20 robotic-assisted cases to 20 manual cases (98 vs. 95 minutes, $p > 0.05$) (►**Tables 4–6**).

Surgeons 1 and 2 Combined Cases

When the first 20 robotic-assisted, last 20 robotic-assisted, and 20 manual cases from surgeons 1 and 2 were combined to create three cohorts, a trend similar to that of the individual analyses occurred. The mean operative times for the combined first 40 robotic-assisted TKA cases and combined last 40 robotic-assisted TKA cases were 99 minutes (range, 71–142 minutes) and 84 minutes (range, 52–123 minutes), respectively, showing a significant decrease in overall operative time ($p < 0.05$). The mean operative times for the combined first 40 robotic-assisted TKA cases and combined 40 manual cases were 99 minutes (range, 71–142 minutes) and 81 minutes (range, 50–142 minutes), showing a significantly shorter operating time for the manual cases ($p < 0.05$). The mean operative times for the combined last 40 robotic-assisted and manual TKA cases were 84 minutes (range, 52–123 minutes) and 81 minutes (range, 50–142 minutes), showing no significant time difference between the manual and robotic cohorts ($p > 0.05$) (►**Tables 7–9**).

Table 4 Surgeon 2 robotic-assisted TKA

	Robotic-assisted cases 1–20 Mean (range)	Robotic-assisted cases 40–60 Mean (range)	*p*-Value
Total (*N*)	20	20	
Time (min)	117 (74–142)	98 (67–123)	<0.005

Abbreviation: TKA, total knee arthroplasty.

Table 5 Surgeon 2 first 20 robotic-assisted TKA versus manual controls

	Robotic-assisted cases 1–20 Mean (range)	20 manual cases Mean (range)	*p*-Value
Total (*N*)	20	20	
Time (min)	117 (74–142)	95 (71–142)	<0.005

Abbreviation: TKA, total knee arthroplasty.

Discussion

Robotic-assisted TKA has shown promise to help orthopaedic surgeons to potentially achieve better accuracy of component placement and soft tissue protection. However, as with most new surgical technologies, there is an associated learning curve before surgeons can expect ease of use to be similar to that of traditional manual cases. Therefore, the purpose of this study was to assess robotic-assisted versus manual operative times to partially understand the learning curve

Table 7 Surgeons 1 and 2 combined robotic-assisted TKA

	Robotic-assisted first combined 40 cases Mean (range)	Robotic-assisted last combined 40 cases Mean (range)	*p*-Value
Total (*N*)	40	40	
Time (min)	99 (71–142)	84 (52–123)	<0.005

Abbreviation: TKA, total knee arthroplasty.

Table 8 Surgeons 1 and 2 first combined robotic-assisted TKA versus manual controls

	Robotic-assisted first combined 40 cases Mean (range)	40 manual cases Mean (range)	*p*-Value
Total (*N*)	40	40	
Time (min)	99 (71–142)	81 (50–142)	<0.001

Abbreviation: TKA, total knee arthroplasty.

Table 9 Surgeons 1 and 2 last combined robotic-assisted TKA versus manual controls

	Robotic-assisted last combined 40 cases Mean (range)	40 manual cases Mean (range)	*p*-Value
Total (*N*)	40	40	
Time (min)	84 (52–123)	81 (50–142)	>0.05

Abbreviation: TKA, total knee arthroplasty.

for robotic arm–assisted TKA. The results from this study highlight two surgeons' experiences using the robotic-assisted TKA device. Although robotic-assisted operative times for each surgeon were initially longer than manual case operative times, each surgeon progressed on their learning curve such that their later robotic-assisted TKAs had similar operative times as manual case operative times. Even when the two surgeons robotic cases were combined, creating a more diverse cohort of robotic cases from different surgeons at different institutions, robotic operative times still were similar to manual operative times.

There were certain limitations to this study, including the nonrandomization of patients. However, while the patients were not randomized and were chosen sequentially, this allowed us to track continuous improvement with using the robotic-assisted device. Further, this study only analyzed two surgeons' experiences with using the robotic-assisted device and categorized their experience based only on operative times. Nevertheless, the study was still a multicenter study and incorporated a wide, diverse group of patients. Further studies should expand on our findings with additional surgeon experiences to provide a more comprehensive learning curve. In addition, future studies should look at short- and long-term patient outcomes using the robot as well as potential cost savings as these factors were not assessed in this study.

Similar to our study, Coon[11] performed a study analyzing the integration of robotic technology for TKA in the operating room, and found that while initial robotic cases could take up to 120 minutes, very quickly, subsequent cases were performed less than 40 minutes. This 40-minute robotic operative time was similar to the group's usual TKA time, further supporting the ability to learn and perform the robotic technique with just as great efficiency as manual cases. In addition, like Coon and many others,[11,13,14] Liow et al[8] performed a prospective study on 27 patients and found the postoperative coronal mechanical alignment after robotic-assisted TKA to be within 3 degrees, further supporting the precise abilities of the robot.

One of the most commonly noted reasons against the use of robotic-assisted devices is the potential for longer operative times.[9,10,15] Yet, while longer operative times were noted in these studies, each study still reported on the robots precision and ability to consistently achieve neutral alignment. Furthermore, the initial time period of our study also showed longer operative times for the robotic-assisted cases than for the manual cases. However, as the surgeons and operating room staff became more familiar with the device, robotic-assisted and manual case operative times became comparable.

The data from this study effectively create a learning curve for the use of robotic-assisted TKA. It should be noted that not only was there a significant decrease in robotic-assisted operative times from the first 20 cases to the last 20 cases for each surgeon but there was also no significant operative time differences between the last 20 robotic-assisted cases and the manual cases. Importantly, this trend in mean operative times remained even when the data from two different surgeons and two different hospitals were combined. As both surgeons completed their total cases numbers within similar time frames, these data imply that within a few months, a board-certified orthopaedic joint surgeon should be able to adequately perform robotic surgery without adding any operative times.

Conflict of Interest

Dr. Mont is a consultant for, or has received institutional or research support from the following companies: Sage Products, TissueGene, OnGoing Care Solutions, DJO Global, Microport, Orthosensor, National Institutes of Health, Stryker, Johnson & Johnson, Pacira Pharmaceuticals, Merz, US Medical Innovations. He is on the editorial/governing board of the *American Journal of Orthopedics*, *Journal of Arthroplasty*, *Journal of Knee Surgery*, and *Surgical Technology International*. He is board or committee member of AAOS.

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Erratum: ►**Tables 6**, **8**, and **9** have been corrected as per Erratum published on March 7, 2018. DOI of the Erratum is 10.1055/s-0038-1635082.