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Assessing the Learning Curve of Advanced Intra-Operative Planning For Total Knee Arthroplasty

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Abstract

New technologies introduction in the operating room induces a cost for the health system which can be assessed. This evaluation should focus on the stages dedicated to this innovation, not on the whole surgical workflow. The aim of this study was to evaluate the learning time for surgeons using a new intraoperative planning technique coupled with instrumented knee laxity measurement.

1 Introduction

New technologies as robotic or navigation used for total knee arthroplasty (TKA) have the potential to improve procedural consistency and ultimately patient outcomes. On the other hand, their adoption has an impact on surgeons' habits. Cumulative summation analysis (CUSUM) makes it possible to monitor this learning phase and react if necessary [2]. A surgeon-dependent learning curve impacting the surgical time has been observed [5, 7, 8]. However, these studies compared the total duration of the surgical procedure, not just the surgical steps during which the new technology was introduced. The use of an instrumented method for knee laxity assessment coupled with a CAOS system enable intraoperative planning of bone cutting parameters in terms of size, alignment, as well as advanced laxity considerations. The purpose of this study was to evaluate the surgeons' learning curve when integrating this new technology into their daily practice, focusing on this intraoperative planning stage.

2 Material and Methods

A retrospective review was carried out on a proprietary cloud-based database archiving cases logs performed using an instrumented CAOS system. This system allows the acquisition of the comprehensive knee joint laxities throughout the full arc of motion under quasi-constant distraction force. Then, the surgeon can perform advanced intraoperative planning of the femoral cut parameters based on size, alignment, as well as soft-tissue considerations. For each selected surgeon, their first 50 cases were considered. For each surgery log, the CAOS system recorded the active time spent on setting up the planning (from the first to the last interaction).

The learning curve was assessed for each surgeon by performing a CUSUM analysis of the time spent on the set-up of the intraoperative planning. The CUSUM values were then plotted in chronological order to evaluate the surgeon-specific learning curve. The perfect learning curve would follow a bell-shaped curve pattern, with the asymptote representing the number of cases required to achieve competence. So, this inflection point in the CUSUM graph is defined as the transition between the learning and the proficiency phases [3].

2.1 Statistical analyses

The duration of the learning phase was analyzed per surgeon and globally (mean ± SD) and its Pearson correlation coefficient with the time required to achieve the first 50 surgical procedures was investigated. Independent samples Student t-test was used to compare continuous variables when assuming equal variance and corrected t-test otherwise. Statistical significance was set at p¡0.05.

3 Results

A total of 450 cases performed by 9 individual surgeons were considered, corresponding to surgeries performed worldwide from August 2021 to April 2023, so a total period of 597 days with a mean by surgeon of 239±98 days to perform their 50 first cases (see Table 1).

	Time required to perform the first 50 surgical procedures (days)	**Number of cases for the learning phase (CUSUM)**
Surgeon 1	305	11
Surgeon 2	154	5
Surgeon 3	197	6
Surgeon 4	389	9
Surgeon 5	148	4
Surgeon 6	362	6
Surgeon 7	262	9
Surgeon 8	108	2
Surgeon 9	225	6
Mean (SD)	239 (98)	6.4 (2.8)

Table 1: Duration of first 50 cases and learning phase.

The CUSUM learning phase varied from 2 to 11 cases, with a mean of 6.4±2.8 cases. As an example, the CUSUM for Surgeon 7 can be seen in Figure 1. For all surgeons combined, the total intraoperative planning mean time in the learning phase was 82 seconds longer than in the proficiency phase (132 vs. 49 sec; p ¡ 0.0001) but, individually, this difference was only significant for 5 of the 9 surgeons.

The correlation coefficient between the learning phase and completion time for the first 50 cases was 0.75 (p=0.0203, 95% CI 0.17 to 0.94).

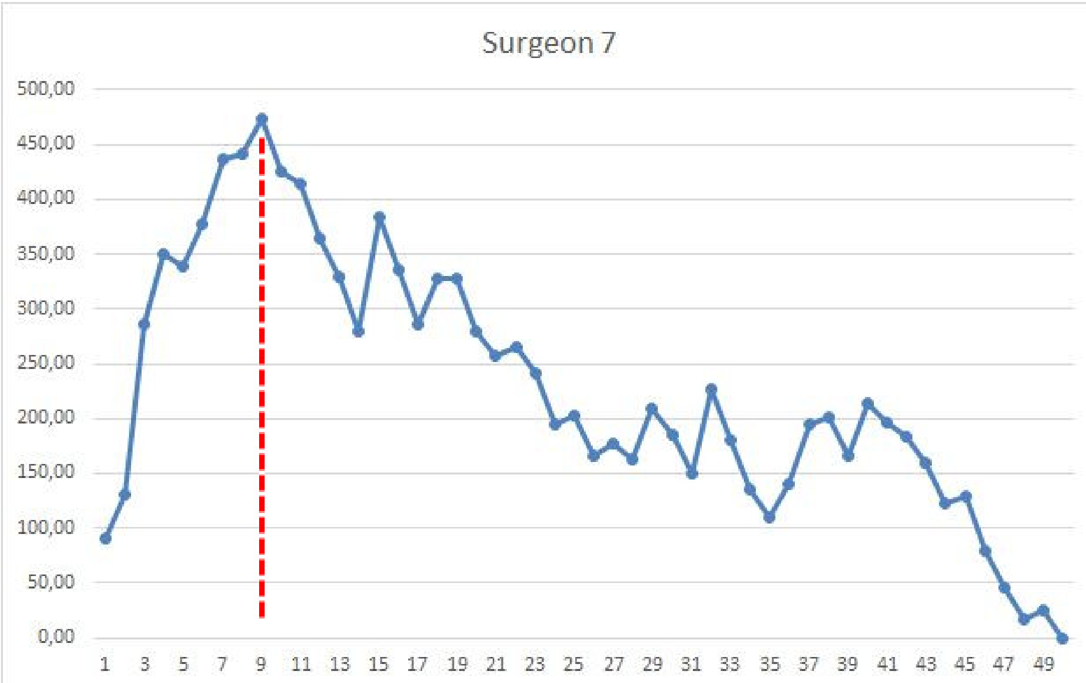

Figure 1: Example of CUSUM for planning time per case, surgeon 7.

4 Discussion and conclusion

CUSUM analysis allows the data collected to be presented in a fashion that enables the assessment of the progression of learning and retrospective analysis of deviations from that progression. Notably, it allows for avoiding the high level of noise of simple duration curve [3].

Recent studies on robot-assisted TKA using CUSUM analysis showed learning curves for total operative time to range from 7 [5] to 43 cases for high volume surgeons [10, 9] and that the operative time after the learning curve did not differ significantly from the conventional technique [4]. With another robotic system, that number varies from a mean of 8.7 [1] to 70 cases [6] for senior surgeons to balance operative time between manual and robotic procedures when introducing the technology. In the present study, the adoption was quicker, with an average of 6.4 cases to achieve the asymptote.

Furthermore, while the previous studies have compared the overall operative time, we focused on analyzing the intraoperative planning step duration only, the stage where the technology has been added. Our study shows that the average planning time is more than halved after the learning phase. Finally, the correlation coefficient analysis seems to show that the faster the 50 first cases are achieved, the shorter the learning curve.

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