Learning Curves for Robot-Assisted Pedicle Screw Placement

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Introduction

Robot-assisted pedicle screw placement is associated with greater accuracy, reduced radiation, shorter hospital stays, and fewer complications. However, there is concern for longer operative times and the training period required to achieve these benefits. Long-term learning curves have not been reported in the literature.

Objectives

We report the learning curves of a surgeon using a robot system.

Materials and Methods

The first 108 spondylolisthesis patients at a tertiary care institution undergoing robot-assisted pedicle screw placement by a surgeon (NT) using the ExcelsiusGPS® system were retrospectively reviewed. Cases occurred between October 2017-May 2022. Operative time and estimated blood loss were evaluated by linear regression.

Experience level analysis: Cases were divided into a learning period consisting of the first 20 operations (Cases 1-20), an intermediate experienced period (Cases 21-87), and an expert period consisting of the last 20 operations (Cases 88-108). One-way ANOVA and post-hoc Tukey tests were performed to evaluate pairwise comparisons.

Cumulative sum analysis (CUSUM): Cases were ordered chronologically, and the mean operative time of the entire cohort was subtracted from each case's operative time. Cases longer than the mean were assigned a positive value, and cases shorter than the mean were assigned a negative value. Each case's distance from the mean was then added to the value from the prior case. The inflection point represents skill mastery.

Results

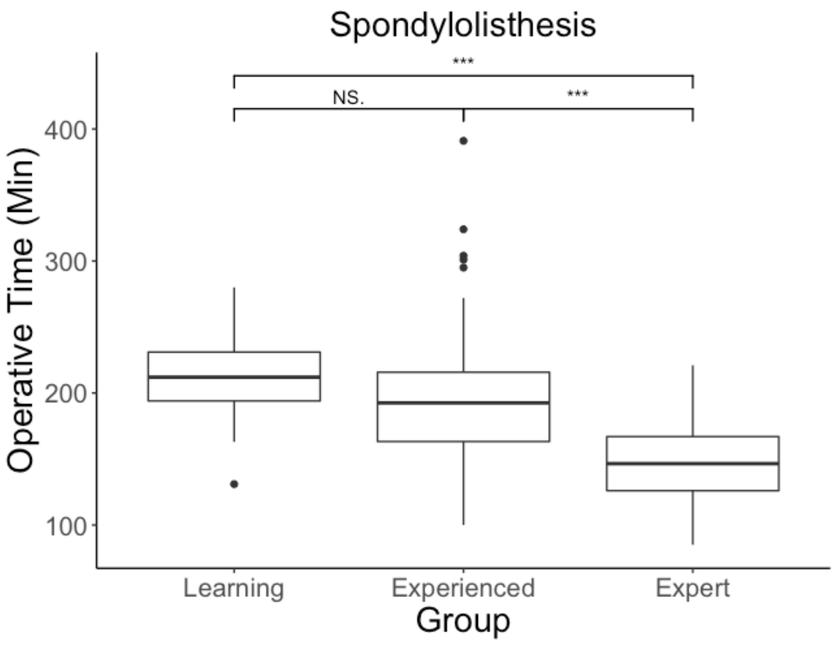

Figure 1. Comparison of operative time with increasing experience.
The mean operative times of the learning, experienced, and expert periods were 212, 197, and 148 minutes, respectively. An ANOVA test demonstrated significant improvement after the initial learning period ($p < 0.001$). The operating time for the first 20 cases was not significantly greater than the experienced cases ($p = 0.44$). Significant decreases in operating time were noted between the experienced and expert periods ($p < 0.001$) and the learning and expert periods ($p < 0.001$).

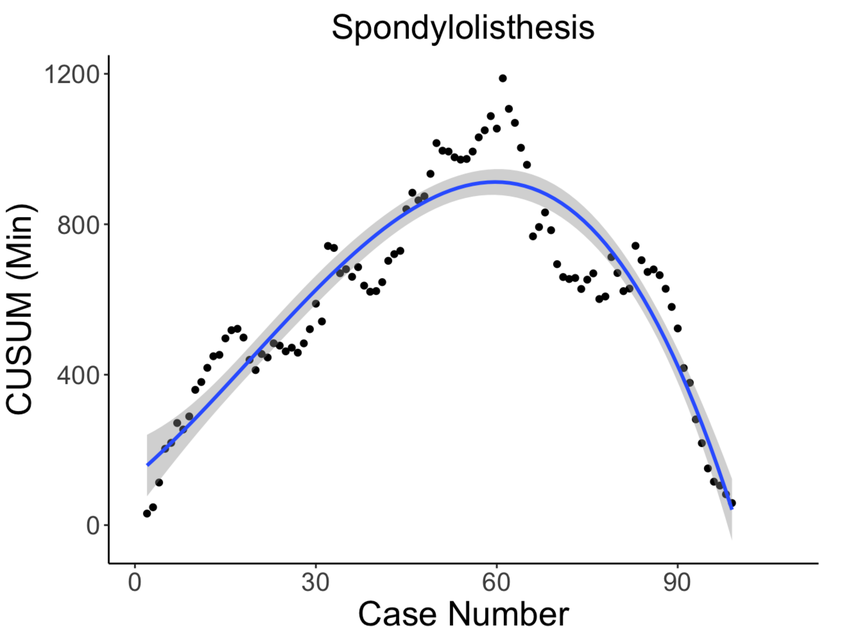

Figure 2. Cumulative sum analysis for spondylolisthesis cases.
The CUSUM analysis resulted in a concave down curve with two phases representing the learning and mastery phases. The inflection point was the 61st case, representing proficiency, and the endpoint was the 99th case.

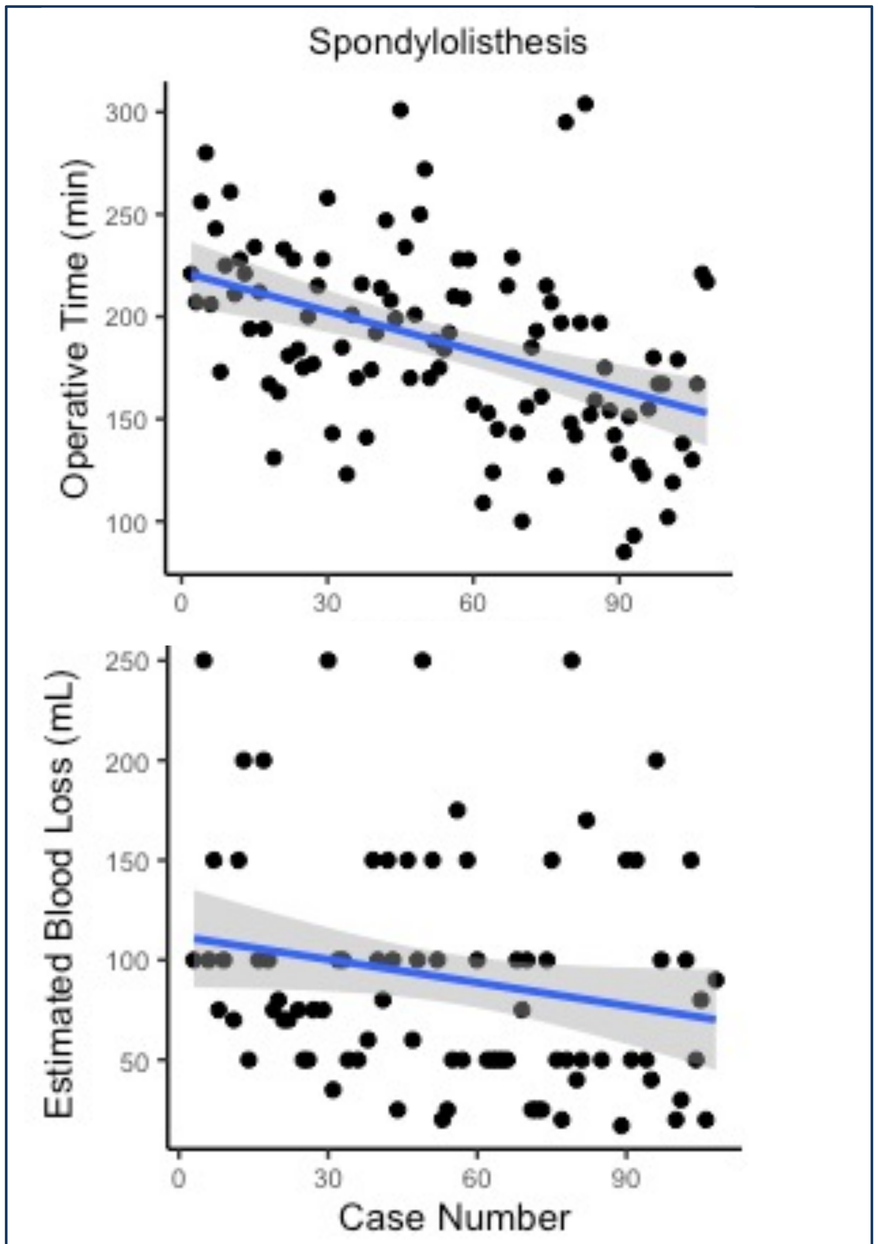

Figure 3. Operative time and estimated blood loss learning curve.
For operative time, a 0.99-minute linear decrease per case was observed ($r = 0.49$, $p < 0.001$). For blood loss, a 0.56 mL decrease per case was observed ($r = 0.24$, $p = 0.05$). Both results were significant. After 108 cases, this represents a reduction of 1.8 hours in operative time and 60 mL in blood loss.

Conclusion

Operative time and blood loss significantly decreased with more experience. A 20-case learning curve is sufficient to reach experienced proficiency, but 61 cases are required to reach expert proficiency. Even after completion of initial training, surgeons can continue to reduce operative time. Disadvantages of robot-assisted surgery are reduced with advanced experience.