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Impact of surgical volume on Neurosurgeon learning curve, retrospective personal study

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Abstract
Introduction: Neurosurgery is difficult to be understood due to the complexity of its operations. This study examines the correlation between the amount of surgeries conducted and operational efficiency over a spectrum of procedures with differing complexity, utilizing complication rate evaluation and institutional standards.
Methods: A retrospective observational study was performed at Dr. Sulaiman Al-Habib Medical Group and Qassim University. From January 2021 to December 2024, 1,647 neurosurgical and spinal patients treated by a single neurosurgeon were included in this study. The cases were divided into three categories: easy (n = 913), medium (n = 412), and hard (n =321). We examined the operative durations for each group of events to assess the impact of the learning curve.
Results: The operation took a lot less time: 25% less for easy situations, 20% less for moderate cases, and 14% less for hard cases. The therapies that worked best were the ones that were easy to grasp and had a lot of people using them. On the other hand, it took longer to make progress with advanced procedures because they needed more technical skill. These numbers show that there is a strong correlation between how many times the treatment is given, how well it works, and how safe the patient is.
Conclusion: More operations influence both safety and efficiency and have significant impacts on operative time. Institutional benchmarks provide fair standards for how well people should do.

Keywords: Neurosurgery, surgical volume, learning curve, operative efficiency, complication rate, retrospective study

Introduction

Neurosurgery is a very advanced and wide field that requires a lot of technical skill, understanding of anatomy, and the capacity to think critically. The brain and spinal cord are very complicated; thus, neurosurgeons have to learn a lot. This means that a neurosurgeon may need to study and practice for years before they are competent at what they do.

A lot of people use the phrase "learning curve" to talk about how much someone learns while doing something.

One thing that all kinds of surgery have in common is that the more you do them, the better they work. This is because doctors who do more surgeries get better at their jobs, make better choices, and find better ways to care for patients before and after surgery.

To become a good neurosurgeon is a long and hard process that depends a lot on how many patients a surgeon sees (Forestier *et al.*, 2018) [6]. The learning curve, which shows how experience in surgery affects performance, is an important part of learning and doing neurosurgery (Go *et al.*, 2020) [8].

Literature Review

New and groundbreaking surgery is essential for improving patient outcomes, yet it may necessitate the acquisition of new knowledge (Frans *et al.*, 2018) [7].

Numerous studies indicate a significant association between the volume of procedures performed and the degree of expertise in various surgical disciplines.

The experience of performing a given surgical procedure with first few patients provides so much immediate natural feedback that all theories of skill acquisition predict rapid improvement of performance (Ericsson, 2004) [4].

But after a certain number of cases, performance improvements usually stop. The amount of people who need this depends on how hard and what kind of procedure it is (Maruthappu *et al.*, 2015) [17, 18].

While low or medium volume centers may not attain optimal outcomes, collaboration and structured training can mitigate disparities and enhance results to align more closely with those of high-volume centers (Maruthappu *et al.*, 2015; Jia *et al.*, 2025) [11, 17, 18].

Higher surgeon volume is associated with lower morbidity and mortality, shorter length of hospital stays, less readmission, and lower hospital costs (Hui-Zi Li *et al.*, 2018) [10]

Dependent on the procedure, experience can serve as a powerful driver of improvement or have clinically insignificant impacts on operative time (Maruthappu M *et al.*, 2015) [17, 18]

Johannes M *et al.*, results in 2016 [13] support a positive volume-outcome relationship for most procedures.

A significant relationship has been evidenced for various surgical procedures (El Amrani M et.al, 2018; Pasquer A et. Al, 2016; Johannes M *et al.*, 2016) [3, 13, 23]; in all cases, a higher operating volume was associated with better patient outcomes (Mathieu L et. Al, 2021) [19].

Statistical methods, such as cumulative summation analysis (Cundy *et al.*, 2015) [2], can be employed to objectively assess the learning curve in surgical practice. CUSUM charts are useful methods to provide visual feedback before significant quality issues arise (Nuria M. & Gonzalo V. 2020) [8, 21].

The shift from the learning phase to the next step depends on the specific surgical task, such as setup time, docking time, console time, operating time, and overall operating room time (Cundy *et al.*, 2015) [2].

We conducted a four-year longitudinal research to evaluate the effect of increased surgical frequency on the learning curve.

Methodology

Location and Structure of the Study

This study analyzed neurosurgical cases performed during a four-year period, from January 2021 to December 2024, at the Dr. Sulaiman Al-Habib Medical Group in Buraidah and the College of Medicine at Qassim University. The research examined the correlation between the frequency of surgeries and the neurosurgeon's learning curve, utilizing a total of 1,647 cases.

Selecting patients and collecting data;

The study encompassed all patients who underwent certain neurosurgical or spinal surgical procedures conducted by a single neurosurgeon during the designated study period. Institutional surgery logs and electronic medical records were used to lock for the cases. To be included, adult patients (over 18 years old) had to have all the information on their surgeries and follow-ups. Patients who didn't have enough information needed emergency surgery or were having operations that weren't normal for the neurosurgeon were not included.

The information that was collected included the patients' demographics (age and sex), the clinical diagnosis, the details of the surgery (type of operation, length of time, and any issues that arose during the operation), and the outcomes after the surgery (length of stay and complication rates).

We divided the processes into three groups based on how hard they were:

1. Simple (like spinal fusions) (913 times) The first 300 instances took an average of 2 hours, the second 300 cases took 1.75 hours, and the third 300 cases took 1.50 hours.
2. Intermediate (such craniotomies for aneurysms, collections, etc.) (412 instances) (The average length for the first 200 cases was 2.5 hours, the second 100 cases were roughly 2.20 hours, and the third 100 cases was 2 hours),
3. Complicated (like removing tumors) (321 times) (the first 100 instances took about 3.5 hours, the second 100 cases took 3.10 hours, and the third 100 cases took 3.00 hours).

Results

1,647 cases included in this study, Spinal Surgery 913 cases and Neurosurgery 733 cases.

Male patients were 828 while Female patients were 817 with Balanced gender distribution (almost 50/50).

Operative Time Analysis by Procedure Complexity

Table 1: Distribution of Cases by Complexity

Group	Example Procedures	Total Cases	Subdivision (by batches)
Simple	Spinal fusions	913	1st 300, 2nd 300, 3rd 300
Intermediate	Craniotomies (aneurysms, collections, etc.)	412	1st 200, 2nd 100, 3rd 100
Complex	Tumor resections	321	1st 100, 2nd 100, 3rd 100

Table 2: Average Operative Time by Complexity and Case Batch

Group	Batch (Cases)	Average Operative Time (hrs)
Simple	1st 300	2.00
Simple	2nd 300	1.75
Simple	3rd 300	1.50
Intermediate	1st 200	2.50
Intermediate	2nd 100	2.20
Intermediate	3rd 100	2.00
Complex	1st 100	3.50
Complex	2nd 100	3.10
Complex	3rd 100	3.00

Things that were seen

1. **How the Learning Curve Affects Things**
- **Easy steps:** cut by 25% (from 2.0 to 1.5 hours).
- **Intermediate procedures:** cut by 20%, from 2.5 hours to 2.0 hours.
- Hard processes went down by 14%, from 3.5 hours to 3.0 hours.

2. **How much better it became**
- It's easier to understand things that are simple than things that are hard.

3. **How many cases there are and how well they work:**
- In straightforward situations, outcomes were plainly improved with an increased sample size.

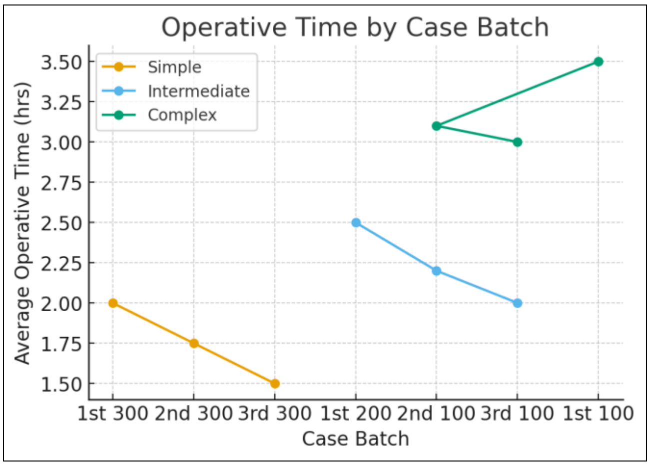


Fig 1: How long will it take for each group of cases

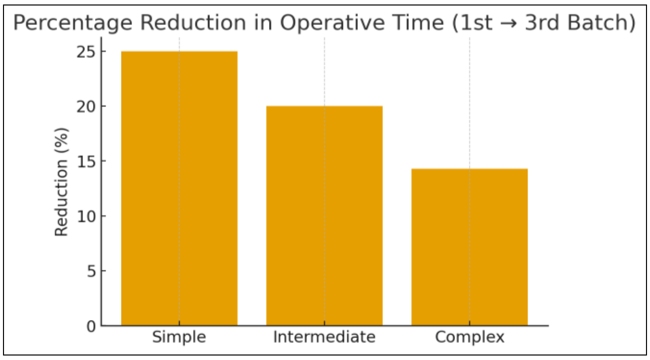
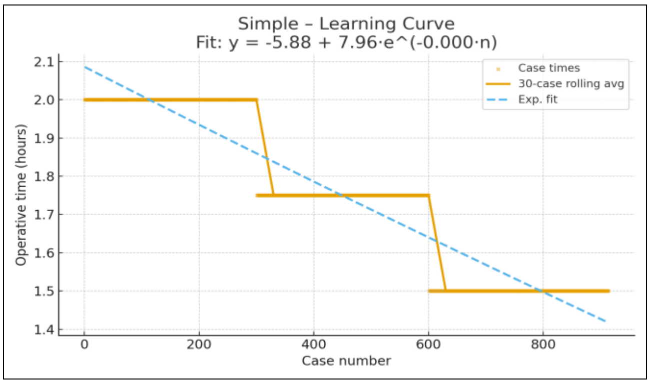
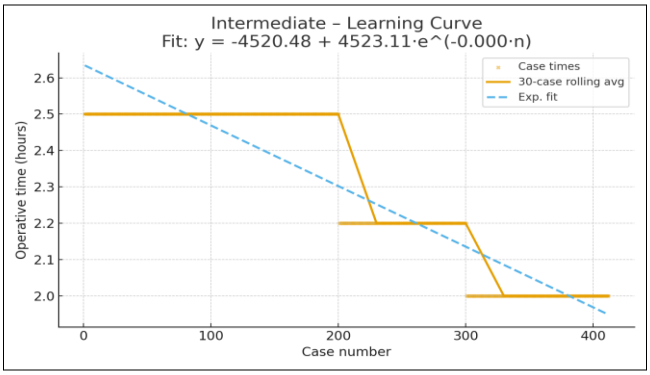


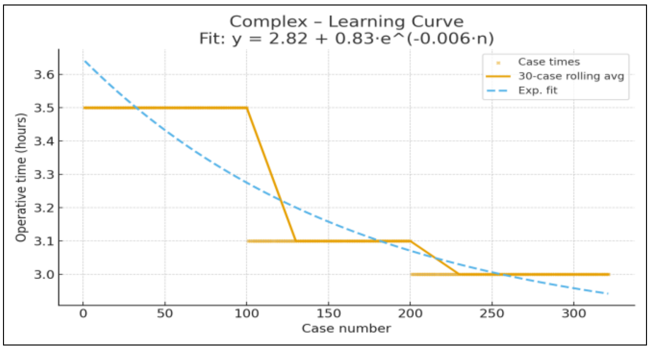
Fig 2: Percentage of Time Decrease for Surgery (1st to 3rd Batch)

Learning Curves

There is a point for each case, a solid line for the 30-case rolling average, and, if possible, a dashed line for an exponential decay fit to show how learning has changed things.







Shorter operating times are better for procedures, and the WHO Surgical Safety Checklist and other studies show that they are also linked to fewer issues.

The WHO Surgical Safety Checklist has shown that

- Cut the chance of problems during surgery from 11.0% to 7.0%
- The death rate went down from 1.5% to 0.8%, which was a statistically significant change ($p < 0.001$).

Discussion

Increased surgical volume positively impacts the learning curve for surgical procedures, enhancing skill acquisition and patient outcomes. Surgical proficiency is known to depend on both the learning curve for a procedure and the case volume of the surgeon. (Simpson et.al, 2017) [24]

The present scoping review of the literature was assessing the volume-outcome relationship. 1,647 cases were analyzed, revealed that the higher surgical workload correlates with a more progression in the learning curve, evidenced by reduced operation times and improved patient outcomes.

At The beginning of this study our cases at that time were limited number of cases, the in surgeries time was prolonged and some cases of minor complications as dural tears and cerebrospinal fluid leaks. These results became a lot better when the number of surgical exposures increased.

This is consistent with previous studies that showed that practicing things repeatedly makes you better at them (Trym R Meling & Torstein R Meling 2021; Jing Peng et. Al, 2025) [12, 25].

The Impact of The Learning Curve

This study showed a considerable learning curve for simpler procedures, such spinal fusions, which took 25% less time to do. This is consistent with earlier studies which show that reduced operating hours for uncomplicated operations correlated with an increased number of cases (Hui-Zi *et al*., 2018, Malik *et al*., 2018) [10, 16]

For surgeries that aren't very demanding, such craniotomies for hematomas or aneurysms, the time dropped down from 2.5 hours to 2.0 hours, which is a 20% decrease.

These results are consistent with Levaillant *et al*. (2021) [15] who stated that in all cases, a higher operating volume was associated with better patient outcomes.

Craniotomy operations require more detailed anatomical planning, and the fact that patients have different problems may help explain why the time for surgery is increasing shorter. The learning curve isn't only about how many instances you see; case mix and difficulty of procedures are also quite important (Nuzhath K et. al, 2013) [22].

In more severe cases, such tumor resections, the process took 14% less time, going from 3.5 hours to 3.0 hours. This illustrates that when things are intricate, there are usually other elements that determine how long the treatment will take, which makes it harder. These results are consistent with Allan Taylor *et al*. (2025) [1] who stated that achieving competence in performing complex neurosurgical operations and learning new techniques after qualification takes time.

The Number of Examples in Relation to their Effectiveness

The greatest way to learn how to do hard neurosurgery is to work with real patients. This study shows that there is a link between the number of cases and efficiency. This is shown by the fact that fewer complex processes take less time. The greater sample size for spine procedures (913 cases) probably had a big effect on how much more efficient they became. In the other two groups There may not have been as many modifications because there were less cases in the intermediate and complex categories (412 and 321, respectively).

The study shows that shorter surgical times are not only more effective, but they also lead to fewer problems and safer patients. The WHO Surgical Safety Checklist and other safety measures can make these changes even better by lowering the number of deaths from 1.5% to 0.8% and the number of complications from 11% to 7%.

Conclusion

This study reveals that the number of processes done influences both safety and efficiency and have significant impacts on operative time. The learning curve varies for different procedures. It takes the longest for patients with more difficult conditions to learn.

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