The Effect of Surgical Time on Perioperative Complications in Pediatric Neuromuscular Scoliosis: A Propensity-Matched Analysis

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Abstract

Title: The Effect of Surgical Time on Perioperative Complications in Pediatric Neuromuscular Scoliosis: A Propensity-Matched Analysis

Background: Neuromuscular scoliosis (NMS) is a spinal deformity that often does not respond well to conservative treatments. As such, surgery is usually required to prevent the progression of the scoliotic curvature. Though, this procedure can be associated with significant morbidity. The reported rates of perioperative complications for the pediatric NMS remains quite high, though quite varied. This study attempted to elucidate the correlation between surgical time and perioperative outcomes in pediatric NMS patients.

Methods: Patients who underwent posterior spinal fusion surgery (PSF) for NMS between January 1, 2010, and December 31, 2019, at a single academic institution were identified using ICD coding and an operational REDCap database. Variables collected included: general demographics, major curve size, curve flexibility, total surgical time, number of segments fused, estimated blood loss, intraoperative and postoperative red blood cell transfusion, length of stay, surgical site infection, postoperative neurologic loss, and 90-day readmission. Standard descriptive statistics, including mean and standard deviation, were calculated. The patients meeting inclusion criteria were distributed into two groups: those with a surgical duration of less than 360 minutes and those with surgical duration greater than 360 minutes. This represented a treatment cohort and control cohort, respectively. These groups were then propensity score (PS) matched using nearest neighbor with a caliper of 0.5. The chi-square and Fisher exact tests were used to compare categorical variables between the groups when appropriate. The Wilcoxon Rank Sum and t-tests were used to compare continuous variables between groups.

Results: A total of 126 patients met inclusion criteria and were identified for propensity score

(PS) analysis. After matching, the impact of surgical duration on infection, 90-day readmission, estimated blood loss, and perioperative transfusion volume showed no statistically significant difference. Of the patients meeting inclusion criteria, there were only 13 infections over the ten years, resulting in a rate of approximately 10.3%. When observing the surgical time over the past ten years, there was a decrease in the duration of the procedure, from roughly 530 minutes in 2010 to 300 minutes in 2019.

Conclusion: Our propensity-matched analysis of 126 patients undergoing primary PSFI demonstrated an inability to reject the null hypothesis regarding the perioperative outcomes selected between shorter and longer surgery duration.

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Chapter 1: Introduction

Neuromuscular scoliosis (NMS) is a spinal deformity that may occur as consequence of various neuromuscular pathologies, including those involving the central nervous system, such as cerebral palsy (1). Neuromuscular scoliosis is frequently progressive and severe, involving much of the spine and pelvis.

Patients with NMS often do not respond well to conservative treatments (e.g., bracing). As such, surgery is usually required to prevent the progression of the scoliotic curvature and can be associated with significant morbidity. Perioperative complications are one of the primary concerns involving surgeries of the spine. The rate of these complications remains high for certain subgroups of scoliosis, with reported rates as high as 75% for NMS patients (2-6), despite advancements in surgical techniques and intraoperative monitoring (7). Given the complexity and heterogeneity of this patient population, increased complication rates are often attributed to a variety of factors, such as the severity of spinal deformity, increased surgical times, and other patient comorbidities (7-9). Complications include deep surgical site infections, neurologic, excessive blood loss, pseudoarthrosis and need for revision surgery.

Though surgical time is often studied as a dependent outcome, to our knowledge, no review specifically addresses the impact of surgical time on perioperative complications. This study aims to investigate surgical times and perioperative complications over the past ten years to evaluate the correlation between outcomes and surgical time in pediatric NMS patients.

Chapter 2: Methods

A review of an operational REDCap spine surgery database at a single academic institution identified patients 10-21 years of age who underwent posterior spinal fusion (PSF) for NMS between January 1, 2010, and December 31, 2019. Data from the electronic medical record was obtained, including operative notes, anesthesia records, discharge summaries, clinical progress notes, and radiographs. This data was cross-referenced with the cohort of patients gathered by the institution's medical records department, which were found by utilizing the International Classification of Diseases (ICD)-9 (737.43) and ICD-10 codes (M41.40) for neuromuscular scoliosis, as well as the Current Procedural Terminology (CPT) codes (22802, 22804) for the PSF procedure.

Patients were excluded if they had undergone a prior PSF surgery, had a staged procedure, underwent an anterior and posterior spinal fusion procedure, required removal of growing devices in concurrent surgery, or if the surgery was discontinued intraoperatively. Patients were also excluded if they had a non-NMS diagnosis, such as idiopathic or syndromic scoliosis.

Demographic and operative data were collected from the medical record which included date of surgery, second surgeon involvement, total surgical time, number of segments fused, estimated blood loss, intraoperative and postoperative red blood cell (RBC) transfusion in cubic centimeters, cell saver transfused in cubic centimeters, as well as total length of stay (LOS) in days, postoperative neurologic loss, surgical site infection, and 90-day readmission. Radiographic data included curve severity (major curve Cobb angle) and curve flexibility on preoperative radiographs closest to the date of surgery. Surgical time was calculated in minutes (surgical incision time until dressing applied) and blood loss was recorded in cubic centimeters (cc). A complication was defined as that which resulted in reoperation, readmission, or residual

disability. The complications were analyzed to ensure they occurred within the perioperative time period (≦ 90 days postoperatively).

The patients meeting inclusion criteria were distributed into two groups: those with a surgical duration of less than 360 minutes and those with surgical duration greater than 360 minutes. This represented a treatment cohort and control cohort, respectively. These groups were then propensity score (PS) matched using nearest neighbor with a caliper of 0.5. The groups were compared statistically for the outcome variables of estimated blood loss, total LOS, surgical site infection, 90-day readmission, and perioperative transfusion. Standard descriptive statistics, including mean and standard deviation, were calculated. The chi-square and Fisher exact tests were used to compare categorical variables between the groups when appropriate. The Wilcoxon Rank Sum and t-tests were used to compare continuous variables between groups. A p-value of ≦ 0.05 was considered significant. Statistical analyses were performed using SAS™ 9.4 software and GraphPad Prism 9™.

This study was approved by the Institutional Review Board (IRB) at the Children's Mercy Hospital (CMH) from December 23, 2020 to December 23, 2021, with a waiver of HIPAA authorization and informed consent (IRB STUDY00001542).

Chapter 3: Results

Of the 177 patients screened in the institution's REDCap database, and the 194 discovered from the medical records list, 126 patients met the inclusion criteria before PS analysis, as shown in Table 1.

Table 1. Unmatched patient demographics and covariates

		Surgery Time <6 hrs	Surgery Time >=6hrs	p-value
		n = 41	n = 85	
Female, n(%)		20 (48.8)	42 (50)	0.898
Insurance, n(%)				0.051
	Public	22 (53.7)	54 (64.3)	
	Private	5 (12.2)	17 (20.2)	
	Both	14 (34.2)	13 (15.5)	
Comorbid Conditions, n(%)				0.480
	1	5 (12.2)	9 (10.7)	
	2	8 (19.5)	10 (11.9)	
	>3	28 (68.3)	65 (77.4)	
Age (years), mean(sd)		13.4 (2.72)	13.5 (2.32)	0.966
BMI (kg/m^2), mean(sd)		19.5 (5.24)	18.9 (4.54)	0.536
Height (cm), mean(sd)		146.5 (14.66)	146.3 (14.63)	0.956
Weight (kg), mean(sd)		42.8 (17.60)	41.1 (14.00)	0.545
Second Surgeon Involved, n(%)		27 (65.9)	38 (44.7)	0.026
Curve Severity (degrees), mean(sd)		74 (16.19)	83 (20.65)	0.015
Number of Segments Fused, median(IQR)*		17 (16-18)	18 (17-19)	0.020
Surgery Year, median(IQR)		2017 (2016-2018)	2014 (2011-2017)	<0.001

* %: Frequency; sd: Standard Deviation; IQR: Interquartile Range

Propensity Score Match

To assess the impact of surgical time more accurately on outcomes, the patients in the treatment cohort were 1:1 PS matched with the patients in the control cohort based on several covariates, including age, body mass index (BMI), comorbid conditions, curve severity, number of segments fused, surgery year, as well as second surgeon involvement. Before PS analysis, these covariates show a significant difference in second-surgeon involved, curve severity, number of segments fused, and surgery year (Table 1.). Once matched, the sample size was 29 patients in each group, and there was no longer a significant difference in the suspected covariates (Table 2).

Table 2. Clinical covariates after matching

		Surgery Time <6 hrs	Surgery Time >=6hrs	Matched p-value
		n = 29	n = 29	
Female, n(%)		16 (55.2)	16 (55.2)	1.000
Comorbid Conditions, n(%)				0.824
	1	3 (10.3)	2 (6.9)	
	2	5 (17.2)	4 (13.8)	
	>3	21 (72.4)	23 (79.3)	
Second Surgeon Involved, n(%)		16 (55.2)	13 (44.8)	0.431
Age (years), mean(sd)		13.1 (2.74)	13.4 (2.38)	0.647
BMI (kg/m^2), mean(sd)		19.3 (4.26)	18.9 (4.74)	0.818
Curve Severity (degrees), mean(sd)		78 (16)	75 (16)	0.615
Number of Segments Fused, median(IQR)		18 (16-18)	18 (17-19)	0.626
Surgery Year, median(IQR)		2017 (2016-2018)	2017 (2016-2017)	0.761

Perioperative Complications Outcomes

We evaluated whether the impact of surgical duration resulted in any change in perioperative outcomes after primary PSFI. In the propensity-matched cohorts, we failed to reject the null hypothesis. Similarly, there was also no difference in intraoperative blood loss, transfusion volume, or LOS (Table 3).

Table 3. Perioperative Outcomes

	Surgery Time <6 hrs	Surgery Time >=6hrs	Matched p-value
	n = 29	n = 29	
Surgical Site Infection, n(%)	3 (10.3)	2 (6.9)	1
90-day Readmission, n(%)	3 (10.3)	2 (6.9)	1
Estimated Blood Loss (cc)*, mean(sd)	986 (431)	1077 (367)	0.395
Periop Transfusion (cc), median (IQR)	320 (300-640)	334 (300-640)	0.875
Total LOS (days), median(IQR)	7 (5-9)	6 (5-9)	0.520

* cc: cubic centimeters

In this data set there were only 13 infections out of 126 patients meeting inclusion criteria, resulting in ~10.3% infection rate over ten years. This rate is similar to or lower than the complications rates found in the literature for similar patient population and outcomes (3,8). The

annual number of infections and readmissions are shown in Figure 1. When examining the surgical times over the past ten years, it was interesting to observe a decrease in duration of surgery, from approximately 530 minutes in 2010 to 300 minutes in 2019, likely due to advances in surgical technique and devices as well as our determination to decrease surgical times (Figure 2).

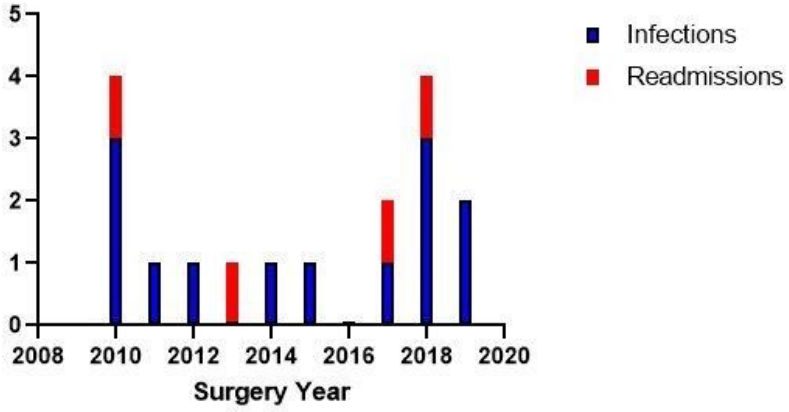

Figure 1. Annual infections and readmissions

Figure 2. Surgical times in past decade

Chapter 4: Discussion

Our propensity-matched analysis demonstrated an inability to reject the null hypothesis regarding the perioperative outcomes selected between shorter and longer surgery duration, with 6 hours as the cutoff. It is important to acknowledge that being unable to detect a difference is likely impacted by a lack of evidence due to the study being underpowered with a small sample size.

The literature regarding the effect of surgical time has been debatable and various studies have attempted to elucidate predictors of perioperative complications in this patient population. Toll, et al, found that intraoperative blood loss and increased surgical time were two variables associated with higher rates of complications (7). Other studies have shown a relationship between surgical time and outcomes in both adult and pediatric surgeries across various surgical specialties, with worse outcomes associated with longer surgeries (10-13), while others did not find an association between surgical time and the outcome of interest (6). In addition, studies evaluating perioperative complications in NMS specifically, seem to have varying complication rates (7, 15) and do mention prolonged surgical time as a predictor of complications, though these studies also acknowledge the limitation of study sample size and power.

Efforts have been made to limit operative duration and time under anesthesia for pediatric patients with scoliosis, including utilizing two surgeons (16, 17). While some reports have shown a decrease in surgical time can be accomplished by utilizing two surgeons, others found no statistical difference, similarly to the opposing results mentioned previously regarding surgical time and complications.

In addition to addressing surgical time as a potential modifiable risk factor for complications, it is important to consider the financial burden of complications on families and

hospitals. The impact of decreasing surgical time may not only improve patient outcomes but can also affect overall costs and allow for more time available to increase case volume (13, 14).

In order to fully reveal a potential association between surgical time and perioperative complications in pediatric NMS, it would be valuable to utilize a larger national database to achieve sufficient study power; this would allow for greater reliability and validity of the research findings.

Several limitations of this study should be considered. First, the retrospective study design has inherent limitations due to utilizing data that has already been collected. Thus, the data utilized in this study is based upon the completion and accuracy of the patient records. Additionally, the recent advances of the electronic health record (EHR), including the conversion from ICD-9 to ICD-10 coding which occurred in 2015, should be taken into consideration. Ideally, to achieve a larger sample size, relevant data prior to 2010 could have been analyzed, but the data before this time within the EHR was less robust and felt it was best if excluded overall.

Lastly, confounding must be considered, especially in observational studies such as this one, including acknowledgement of potential unknown and unmeasured confounders. Due to this, PS analysis was utilized to normalize the differences between the cohorts. When the complexity of this patient population as well as existing and potential covariates were taken into consideration, PS analysis was used to address multiple covariates. However, PS analysis works better for much larger sample sizes, since matching greatly reduces the total number of subjects, sometimes by over 50%. The results of this study in particular may be unable to show statistical significance due to the reduced sample size and accompanying loss of statistical power.

Our propensity-matched analysis of 126 patients undergoing primary PSFI demonstrated an inability to reject the null hypothesis regarding the perioperative outcomes selected between

shorter and longer surgery duration. Future studies should focus on achieving substantial patient numbers through multicenter study to improve power and statistical analysis.

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