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Quality, Safety, and Value Initiative

Reducing Transfusions in Neuromuscular Spinal Fusion: A National Surgical Quality Improvement Program–Pediatrics Quality Improvement Project

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ABSTRACT

Background: Pediatric spinal fusion can result in substantial blood loss, particularly in patients with scoliosis related to underlying neuromuscular (NM) disease. Transfusion is frequently required but carries risks including transfusion reactions, alloimmunization, volume overload, and infection.

Local problem: The American College of Surgeons National Surgical Quality Improvement Program–Pediatrics (ACS NSQIP-P) is a nationally validated, risk-adjusted national outcomes registry. At our institution, ACS NSQIP-P data identified our institution as a high outlier in transfusion for neuromuscular scoliosis patients.

Methods: A multidisciplinary group convened from January 2024 to June 2024 to design and implement a perioperative pathway with the primary goal of reducing transfusion volume to <25 mL/kg and the secondary goal of reducing overall transfusion volume. The final pathway was formally launched in September 2024.

Interventions: The pathway standardized care across all phases of surgery: preoperative optimization through multidisciplinary review and dedicated clinic visits; intraoperative blood conservation with tranexamic acid, controlled hypotension, cell salvage, standardized lab monitoring, and transfusion thresholds; and postoperative protocols limiting red blood cell transfusion and establishing pediatric intensive care unit guidelines. All departments received targeted education and outcomes were monitored with NSQIP-P data.

Results: In the baseline period of July 2023 to December 2023 (n = 13), the median transfusion volume was 9.3 mL/kg, with 6 patients (46%) exceeding 25 mL/kg (median excess transfusion = 25.8 mL/kg). When the team began meeting between January 2024 and June 2024 (n = 13), the median transfusion volume was 14.4 mL/kg, with 2 patients (15%) exceeding 25 mL/kg (median excess transfusion = 11.4 mL/kg). In the subsequent period, July 2024 to December 2024 (n = 19), the median transfusion volume decreased to 5.1 mL/kg, with 2 patients (11%) exceeding 25 mL/kg (median excess transfusion = 4.6 mL/kg). In the most recent period of January 2025 to June 2025 (n = 13), the median transfusion volume was 7.5 mL/kg with 2 patients (15%) exceeding 25 mL/kg (median excess transfusion = 3.7 mL/kg). At the end of the study interval, our institution was no longer identified as an NSQIP-P outlier and was performing “as expected” in this category.

Conclusions: Implementation of a multidisciplinary, evidence-based, perioperative pathway that includes patient optimization before surgery, balanced transfusions intraoperatively, correction of coagulopathy, and a lower transfusion target of 7 g/dL in stable patients postoperatively, can safely reduce transfusion exposure after NM spinal fusion.

Key Concepts:

(1) Excessive blood transfusion in neuromuscular spinal fusion is common and associated with adverse outcomes, including infection, transfusion reactions, volume overload, and increased health care costs.

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- (2) The American College of Surgeons National Surgical Quality Improvement Program–Pediatrics is a validated outcomes registry that enables institutions to benchmark performance against others.
- (3) Implementation of a multidisciplinary, perioperative quality improvement pathway spanning preoperative, intraoperative, and postoperative phases, reduced transfusion requirements in neuromuscular patients undergoing spinal fusion at our institution.

Introduction

Pediatric spinal surgery is frequently associated with substantial blood loss, with volumes varying according to procedure type, surgical technique, and patient comorbidities [1]. As a result, perioperative blood transfusion is common, with more than half of pediatric patients requiring transfusion in some series [2]. Transfusion carries risks, including transfusion reactions, alloimmunization, and infectious complications such as viral transmission and bacterial sepsis [3]. In addition to clinical risks, transfusions increase healthcare costs and place added burden on patients [4,5]. Allogenic transfusion has also been associated with higher rates of postoperative surgical site infection, potentially due to immunomodulatory effects [6–8].

Neuromuscular (NM) spinal deformity encompasses a heterogeneous group of conditions, including central neurologic, central motor neuron, peripheral neurologic, peripheral motor neuron, mixed central and peripheral, and muscular etiologies [9]. Examples include cerebral palsy, hereditary ataxia, syringomyelia, hereditary motor and sensory neuropathy, myelomeningocele, and Duchenne myopathy among other disorders [9].

Patients with NM spinal deformities often have significant comorbidities and are at increased risk for surgical complications [10]. Compared with idiopathic scoliosis, NM scoliosis carries a particularly high transfusion risk; preoperative recombinant erythropoietin, for example, has been shown to be less effective in reducing transfusion requirements among NM scoliosis patients compared with those with idiopathic scoliosis [11,12]. Moreover, a NM indication itself is an independent predictor of increased allogenic blood transfusion [2,13,14]. Reported estimated blood loss in NM posterior spinal fusion surgery ranges from approximately 1,700 to 2,700 mL depending on perioperative strategies and antifibrinolytic use [15]. Reported transfusion rates for these cases range from 55% to 77% [16].

The American College of Surgeons National Surgical Quality Improvement Program–Pediatrics (ACS NSQIP-P) is a nationally validated, risk-adjusted national outcomes registry designed to improve surgical quality across participating institutions [17]. Hospitals receive regular reports detailing complication rates by procedure, enabling benchmarking against national data. At our institution, ACS NSQIP-P identified high transfusion rates in patients with NM disorders undergoing spinal fusion, designating us as an outlier relative to other centers. During 2023, our institution had a major transfusion rate of 42% for NM spinal fusion, corresponding to the 90th percentile in NSQIP-P benchmarking. Given both the inherently higher risk of transfusion in NM patients and the well-documented complications of transfusion, it was imperative to address this deficiency. In response, we convened a multidisciplinary team to develop and implement a perioperative pathway aimed at reducing transfusion use. Our primary goal was to decrease the total red cell transfusion volume to below 25 mL per kilogram (kg), with a secondary goal of reducing overall transfusion volume.

Methods

This study was reported in accordance with the Standards for Quality Improvement Reporting Excellence version 2.0 guidelines [18,19]. Our institutional review board reviewed and approved this project.

Setting and data

This quality improvement (QI) initiative was conducted at a single quaternary care children's hospital located in one of the most diverse cities in the United States. This was a multi-surgeon project and included patients aged 0-17 years who underwent spinal fusion for NM deformity including both primary fusions and revisions.

Data were obtained exclusively from the ACS NSQIP-P. NSQIP-P was selected as the data source because it is nationally validated, risk-adjusted, sampling-based, and benchmarked across participating sites, thereby enabling standardized comparisons and ensuring data quality.

For NSQIP-P reporting, odds ratios (ORs) are used as site-level quality metrics. ORs are derived from comparing the odds of an event to the average odds at all sites. Outlier status is assigned when a site's 95% CI for the OR does not cross 1.0. For this project, the relevant quality metric was major blood transfusion in NM spinal fusion, which is defined as red blood cell transfusion ≥ 25 mL/kg (including intraoperative and postoperative transfusions within 72 hours of surgery start time). This metric encompasses allogenic, autologous, and cell-saver transfusions. Excess volume was calculated as transfusion volume minus 25 mL/kg.

The key metrics analyzed were as follows: (1) the number of patients receiving ≥ 25 mL/kg, (2) total transfusion volume (mL/kg), and (3) whether our institution was designated as an NSQIP-P outlier. These outcomes were reviewed continuously as NSQIP-P data became available and were reported monthly in spine deformity outcomes meetings and multidisciplinary conferences. NSQIP-P data are released every 6 months (January and July) but each report summarizes outcomes over the preceding 12-month period.

Planning

A multidisciplinary planning group was established with representation from orthopaedic surgery, anesthesiology, critical care medicine, transfusion medicine, nursing, and surgical quality team members. The team met regularly between January and June 2024 to review institutional data, examine relevant literature and guidelines, and develop a comprehensive care plan for NM spinal fusion. As part of the planning process, potential contributors to our outlier transfusion rates were identified and organized using an Ishikawa (fishbone) diagram (Fig. 1).

Interventions

Based on findings from the planning phase, a multidisciplinary pathway was developed and implemented, spanning preoperative, intraoperative, and postoperative care. Department-wide education occurred in August and September 2024 and the final pathway was formally launched in September 2024.

Preoperative interventions

A 4-step process was created to ensure optimization prior to surgery: (1) indications review with documentation in the electronic medical record, (2) Pediatric Anesthesia Screening Service (PASS) clinic visit 2-3 months before surgery for the baseline evaluation, (3) multidisciplinary review to confirm readiness and notify perioperative teams, and (4) a

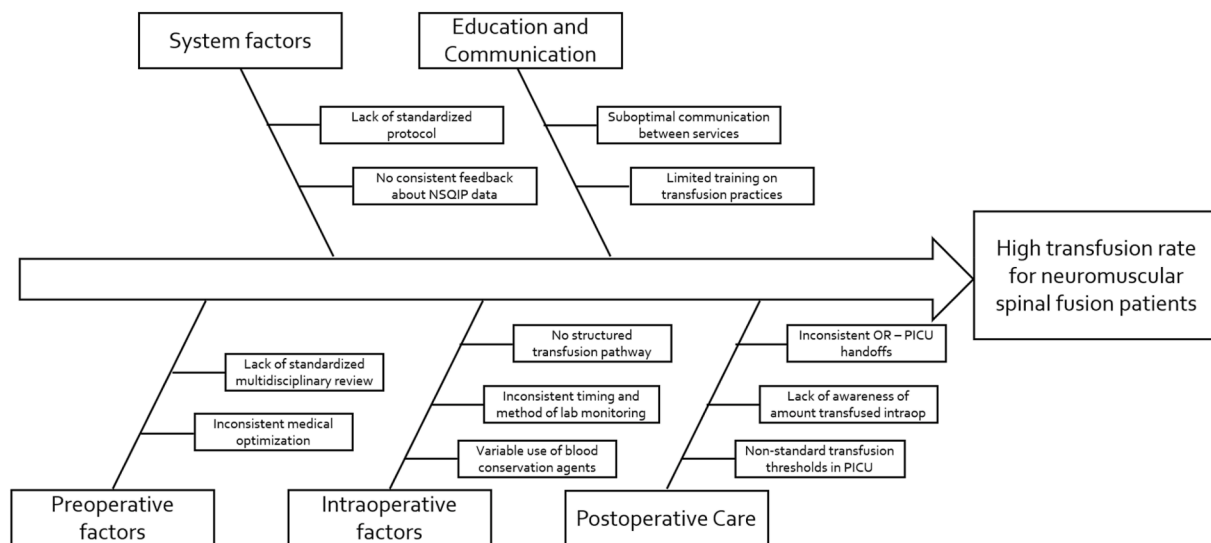


Figure 1. Fishbone diagram illustrating potential contributing factors to high transfusion rates for neuromuscular spinal fusion patients.

second PASS clinic visit 10-14 days before surgery to finalize optimization. The indications review served as a multidisciplinary checkpoint to confirm surgical appropriateness and timing in the context of the patient’s NM diagnosis and comorbidities. The indications review was designed to identify patients deemed excessively high risk and, when appropriate, remove them from the surgical schedule. The first PASS visit functioned as an early comprehensive assessment to identify medical, nutritional, pulmonary, and hematologic risk factors, allowing sufficient time for subspecialty consultation and optimization. At this visit, standardized preoperative laboratory testing and specialist consultations were ordered, including pulmonary, nutrition, physical medicine and rehabilitation, and other subspecialties as indicated. The multidisciplinary review ensured findings from the initial PASS visit and subspecialty consultations were reviewed collectively with the goal of confirming surgical readiness, anticipating intraoperative and post-operative needs, and coordinating anesthesia, transfusion, and critical care planning. The second PASS clinic visit served as the final readiness assessment to confirm completion of optimization measures and to finalize perioperative logistics. At this visit, patients received the type and screen for 4 units of red blood cells and 1 apheresis unit of platelets; plasma and cryoprecipitate were ordered if indicated and held for availability in the operating room.

Intraoperative interventions

Anesthetic and surgical teams employed a standardized blood conservation strategy that included tranexamic acid, controlled hypotension, and routine use of cell salvage. Cell salvage was used whenever available. A structured intraoperative transfusion pathway (Fig. 2) was developed, requiring laboratory assessment every 30-60 minutes with product transfusion guided by prescribed thresholds. Patients received red blood cells for hemoglobin <10 g/dL, platelets for platelet count <100,000/μL, plasma for interquartile range >1.5, and cryoprecipitate for fibrinogen <200 mg/dL. An emphasis was placed on communication across teams on balancing transfusions with hemodynamic goals. Total intravenous anesthesia technique and subanesthetic inhalational agents were used to maintain hemodynamics.

Postoperative interventions

All NM spine patients were admitted to the pediatric intensive care unit for the first 48 hours postoperatively, with earlier transfer only by agreement between the surgical and critical care teams. Standardized orders included laboratory monitoring, respiratory support, pain

management, early mobilization, and nutrition consultation within 72 hours. Restrictive transfusion thresholds were adopted, with red blood cells limited to clinically significant bleeding, hemodynamic instability, or hemoglobin <7 g/dL. If stable, transfusion was given in 5-10 mL/kg increments limited to a maximum of 1 unit at a time before reassessment. Balanced transfusion with fresh frozen plasma, platelets, and cryoprecipitate was used when indicated, with an emphasis on early correction of any coagulopathy.

Results

During the baseline period (July 2023 to December 2023), 13 patients underwent NM spinal fusion. The median transfusion volume was 9.3 mL/kg, and 6 patients (46%) received ≥25 mL/kg, with a median excess transfusion volume of 25.8 mL/kg among that subgroup.

The QI team began meeting between January 2024 and June 2024. In this period, 13 patients underwent NM spinal fusion with a median transfusion volume of 14.4 mL/kg. Two patients (15%) received ≥25 mL/kg (median excess transfusion = 11.4 mL/kg).

In the subsequent NSQIP-P reporting period (July 2024 to December 2024), which included both pre- and post-implementation cases, 19 patients underwent NM spinal fusion with a median transfusion volume of 5.1 mL/kg. Two patients (11%) received ≥25 mL/kg (median excess transfusion = 4.6 mL/kg).

In the last reporting period (January 2025 to June 2025), after full implementation, the median transfusion volume was 7.5 mL/kg (n = 13). Two patients (15%) received ≥25 mL/kg (median excess transfusion = 3.7 mL/kg). During this period, our institution was no longer identified as an NSQIP-P outlier for transfusion in NM spinal fusion.

A control chart illustrating transfusion volume per weight over time is shown in Fig. 3. Annual NSQIP-P benchmarking data are summarized in Table 1. These data are reported by NSQIP-P in 12-month intervals and include major transfusion rates (cases exceeding 25 mL/kg), whether institutions are designated as outliers, and adjusted percentile rankings for major transfusions. Table 1 illustrates our institution’s 2023 NSQIP-P benchmarking results, including our designation as an outlier for NM spinal fusion major transfusions, corresponding to the 90th percentile nationally. These metrics are not available in 6-month reporting periods. Because the 12-month intervals used in Table 1 overlap with the 6-month study periods used in the analysis, the number of cases differs from those presented in Table 2. Table 2 presents 6-month interval data used to evaluate temporal changes across the planning, implementation, and post-implementation phases.

Perioperative Transfusion of Blood Products for Spinal Fusion Procedures Evidence-Based Informed Pathway

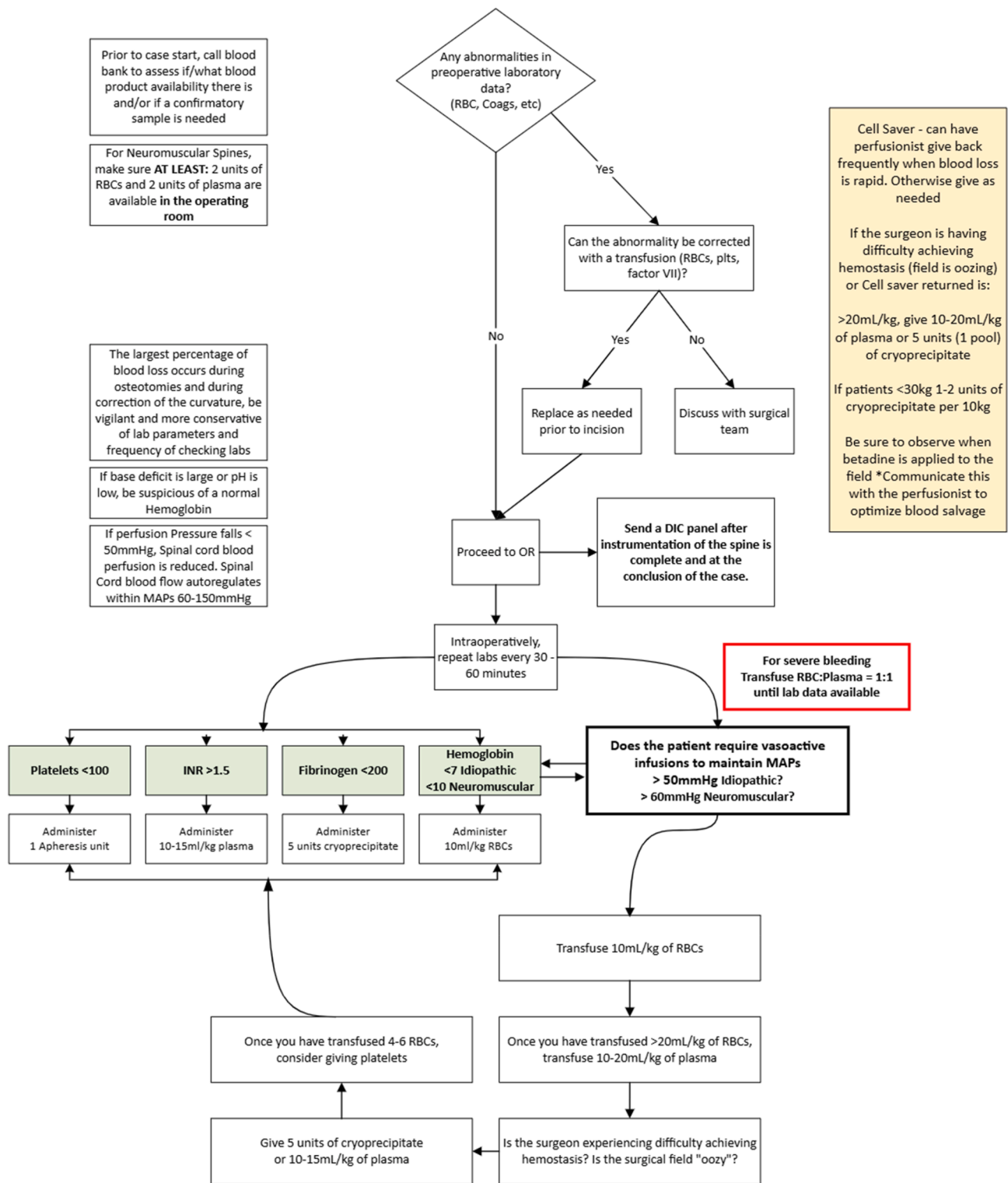


Figure 2. Intraoperative transfusion pathway.

Control chart analysis demonstrated special cause variation (defined as a nonrandom change in the underlying process) after implementation, consistent with a real and sustained change in practice (Fig. 3).

There was no increase in postoperative morbidity, surgical site infection, unplanned readmission, or hospital length of stay throughout the study.

Control Chart: Transfusion Volume per Weight Over Time

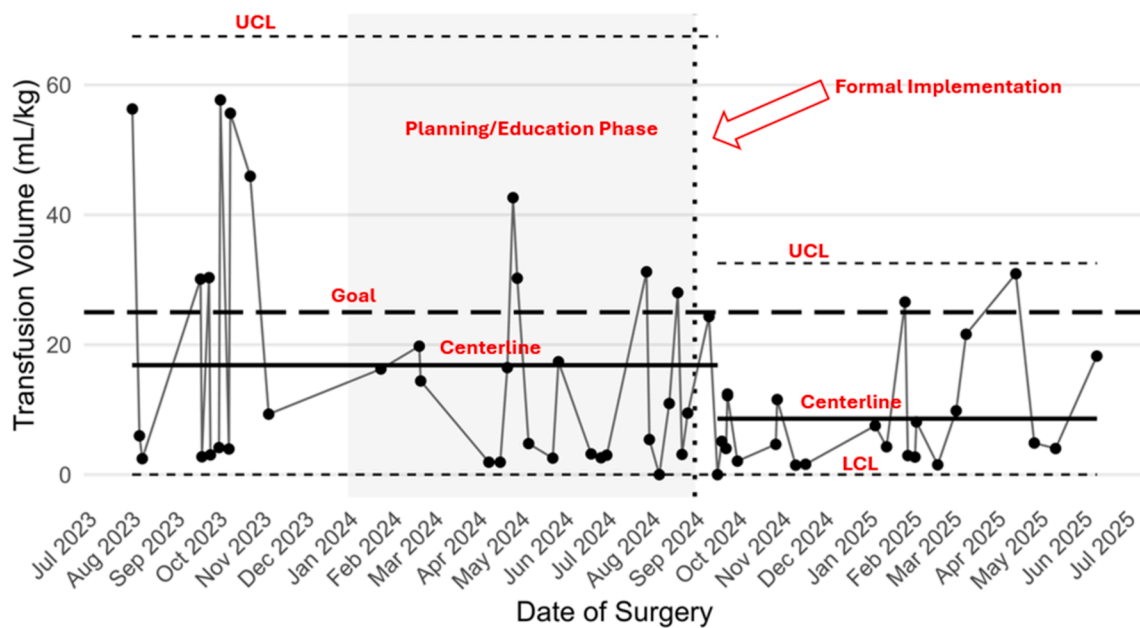


Figure 3. Control chart of transfusion volume per weight (mL/kg) over time in neuromuscular spinal fusion patients. Each point represents an individual patient. The shaded region denotes the planning/education phase (January to September 2024). The dotted vertical line marks formal implementation of the initiative (September 2024). The solid horizontal lines indicate centerlines (mean transfusion volumes) and dashed lines represent upper (UCL) and lower control limits (LCL). The long-dashed horizontal line indicates the NSQIP-P threshold for major transfusion (25 mL/kg). *NSQIP-P, national surgical quality improvement program–pediatrics.*

Table 1.

NSQIP-P summary data over the study period. NSQIP-P reports are released semiannually but each report reflects a 12-month period.

| Time period | Cases | Major transfusions (cases exceeding 25 mL/kg) | Institution designated as an Outlier | Institution's adjusted percentile for major transfusions |
|--------------------------------------|-------|---|--------------------------------------|--|
| January 1, 2023 to December 31, 2023 | 24 | 42% | Yes | 90 |
| January 7, 2023 to June 30, 2024 | 26 | 31% | No | 78 |
| January 1, 2024 to December 31, 2024 | 32 | 13% | No | 39 |

NSQIP-P, national surgical quality improvement program–pediatrics.

Discussion

Pediatric spinal surgery, particularly in patients with NM pathology, is associated with high rates of blood transfusions, exposing patients to risks such as infection, alloimmunization, and increased costs [1–5]. We aimed to decrease transfusion volumes in NM spinal fusion at our institution through a structured QI initiative. Following implementation of a multidisciplinary pathway spanning preoperative, intraoperative, and postoperative care, we achieved a marked reduction in transfusion requirements, and our institution was no longer identified as an NSQIP-P outlier. Moreover, not only did the number of cases exceeding the transfusion threshold (≥ 25 mL/kg) decrease but the median volume of excess transfusions also declined. To our knowledge, this is the first QI report specifically targeting NSQIP-P transfusion benchmarks in NM spinal fusion.

Table 2.

Six-month interval NSQIP-P institutional transfusion data. This table summarizes performance in fixed 6-month blocks. Transfusions were considered excessive if they were ≥ 25 mL/kg. Excess volume was calculated as transfusion volume minus 25 mL/kg.

| Time Period | Cases | Median transfusion (mL/kg) | Number of outliers (cases exceeding 25 mL/kg) | Median excess transfusion (mL/kg) |
|--------------------------------------|-------|----------------------------|---|-----------------------------------|
| January 7, 2023 to December 31, 2023 | 13 | 9.3 | 6 | 25.8 |
| January 1, 2024 to June 30, 2024 | 13 | 14.4 | 2 | 11.4 |
| January 7, 2024 to December 31, 2024 | 19 | 5.1 | 2 | 4.6 |
| January 1, 2025 to June 30, 2025 | 13 | 7.5 | 2 | 3.7 |

NSQIP-P, national surgical quality improvement program–pediatrics.

A variety of strategies have been employed to minimize blood loss and reduce the need for transfusion in pediatric spinal surgery. Preoperative measures include optimizing hemoglobin levels and, in some cases, autologous blood donation; intraoperative approaches involve antifibrinolytic agents and blood conservation techniques, while postoperative strategies focus on restrictive transfusion thresholds and careful monitoring of hemoglobin levels [5,14,20–24].

Our pathway included comprehensive interventions at each stage of care, including standardized indications review, dedicated

multidisciplinary clinic visits, intraoperative transfusion thresholds with balanced components, and restrictive postoperative transfusion practices. The success of this initiative underscores the importance of a multidisciplinary, system-level approach that engages all stakeholders across the perioperative period.

Rates of transfusion in pediatric spinal surgery vary widely, ranging from 36% to 75%, and are consistently higher in NM patients [1,3,5,14,25]. Several groups have demonstrated the value of multimodal, team-based interventions. Fernandes et al. [25] reduced transfusion rates in NM spinal surgery from 98.7% to 66% after implementing a program that included preoperative hemoglobin optimization with iron and erythropoietin, multidisciplinary evaluation for NM patients, intraoperative blood-sparing measures such as tranexamic acid, controlled hypotension with remifentanyl, and meticulous hemostatic technique, as well as restrictive postoperative transfusion thresholds. Similarly, Dick et al. [5] reported a progressive decline in transfusions from 96% to 39.6% through introduction of cell salvage, antifibrinolytics (initially aprotinin then tranexamic acid), a nurse-led optimization clinic to address preoperative hemoglobin, intraoperative hypotensive anesthesia and other conservation strategies, and ultimately a transfusion awareness program with strict postoperative thresholds. Hassan et al. [14] described a transfusion rate of 36% in NM scoliosis after implementation of a blood management protocol, although baseline rates were not reported.

While Fernandes et al., Dick et al., and Hassan et al. [5,14,25] all included NM patients and had significant results, they did not focus exclusively on this population as in our study. Many of their interventions overlapped with ours including hemoglobin optimization, multidisciplinary review, intraoperative blood conservation, and restrictive postoperative thresholds. Our initiative extended these principles by creating a comprehensive, NM-specific pathway. This included multiple structured preoperative clinic visits, formalized multidisciplinary review, and standardized transfusion protocols across all departments. Unlike prior reports, our project also provided a detailed, standardized institutional protocol, which may enhance reproducibility and sustainability.

Strengths and limitations

Strengths of this project include its multidisciplinary design, system-level implementation, and incorporation of all perioperative phases, which enhances sustainability. The use of ACS NSQIP-P ensured high quality data and allowed objective benchmarking against national performance. Our outcome was concrete and clinically meaningful, targeting both transfusion thresholds and outlier status.

Limitations include the single-center design, which may affect generalizability, as resources available in quaternary care centers may not be available in all settings. Because multiple interventions were introduced simultaneously, the relative contribution of each cannot be isolated, limiting replicability for centers with fewer resources. We also observed a decrease in transfusions after initial multidisciplinary meetings, suggesting that increased awareness may have contributed to practice change and early improvements. Although NSQIP-P data are risk adjusted, they do not capture all potential confounders such as surgical technique. At our center, there were no changes in surgical technique or intraoperative management, and case severity was consistent across the period of the study. Because NSQIP-P data are reported semiannually, the July 2024 to December 2024 reporting period contained both pre- and post-implementation cases, which may have diluted the observed effect. Nonetheless, sustained improvement in 2025, when all cases were post-implementation, supports the effectiveness of our initiative.

Conclusion

Implementation of a multidisciplinary, evidence-based, perioperative pathway that includes optimization in preoperative, intraoperative, and postoperative phases can reduce transfusion exposure in NM spinal fusion. This project highlights the value of continuous review of national benchmarking data, the power of multidisciplinary collaboration to improve perioperative outcomes, and offers a sustainable model for eliminating NSQIP-P outlier status for transfusion.

Additional links

- POSNAcademy: [How to Minimize Blood Loss and Minimize Transfusion Risk](#)
- POSNAcademy: [Neuromuscular Scoliosis](#)

Ethics approval and consent

The author(s) declare that no patient consent was necessary as no images or identifying information are included in the article.

Author contributions

Holden Archer: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Venessa L. Pinto:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Farrah Russell:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Valentina Briceño:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization. **Melissa Ard:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation. **Lisa Hensch:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Jun Teruya:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Tanisha G. Daugherty:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Wallis Molchen:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Ryan D. Coleman:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Darrell Hanson:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Frank T. Gerow:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Nicole I. Montgomery:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

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Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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