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NON-IDIOPATHIC SCOLIOSIS

Predictors for postoperative gastrointestinal complications in pediatric non-idiopathic scoliosis patients

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Abstract

Purpose Non-Idiopathic scoliosis (NIS) patients reportedly have higher postoperative complication rates compared to those with adolescent idiopathic scoliosis (AIS). However, there are limited data on the prevalence of gastrointestinal (GI) complications postoperatively, and the preoperative indicators that may predict them. This study aimed to determine the incidence and risk factors of postoperative gastrointestinal (PG) complications after neuromuscular/syndromic scoliosis corrective surgery.

Methods 163 NIS patients underwent spine deformity corrective procedure between 2005 and 2020. Radiographic, surgical, and clinical data were assessed. Patients were stratified based on postoperative GI complication status (PG vs. NPG) and ambulatory status (AMB vs. NAMB, based on GMFCS levels). Clavien–Dindo–Sink classification system was used to separate surgical complications based on severity. Wilcoxon-Rank Sum, Fisher's Exact, Chi-square, and McNemar's tests were utilized. Multivariable logistic regression was conducted. Matched analysis between NIS and AIS patients was conducted with 13 + levels fused.

Results There were 163 patients; 40 (24.5%) patients developed postoperative GI (PG) complications. The overwhelming majority of PG patients (39/40 patients, 97.5%) exhibited one or more minor complications with only 2/40 (5%) major complications; one patient had both 1 major and 1 minor. A greater portion of PG patients had pre-existing GI comorbidities ($p < 0.001$) and were non-ambulatory ($p = 0.003$). Non-ambulatory patients had more pre-existing GI comorbidities (< 0.001) and GI complications ($p = 0.003$) than ambulatory patients. Patients with pre-existing GI diseases had 5.34 times greater odds of developing a postoperative GI complication ($p < 0.001$), specifically those with a G-tube and followed by GI.

Conclusion Non-ambulatory patients are more likely to exhibit GI complications. Pre-existing GI comorbidities, specifically G-tube and being actively followed by a GI specialist are high risk factors for postoperative GI complications.

Keywords Neuromuscular scoliosis · Gastrointestinal complications · Non-ambulatory · Posterior spinal fusion

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Introduction

Scoliosis among pediatric neuromuscular patients is common, with higher incidences depending on the underlying pathophysiology [1]. Failure to perform corrective surgery can lead to significant comorbidity, including respiratory compromise, pain, and issues with sitting and upright balance [2]. When compared with adolescent idiopathic scoliosis (AIS), surgical deformity correction for those suffering from neuromuscular scoliosis (NMS) or syndromic diagnoses, defined as non-idiopathic scoliosis (NIS) in this study, carries an increased risk of complications [3–5]. One adverse outcome this vulnerable patient population faces is postoperative gastrointestinal (PG) complications [6–8].

Studies that have investigated NMS complication rates have highlighted gastrointestinal (GI) complications [6, 7, 9]. Bureta et al. identified NMS etiology as a risk factor for postoperative ileus after scoliosis correction [10]. NIS patients are not only more prone to PG complications but also tend to have more pre-existing GI comorbidities such as gastroesophageal reflux disease (GERD), motility disorders, and aspiration [7]. These comorbidities increase risks of dysphagia, malnutrition, and prolonged feeding times in NIS patients [2]. Given the heightened risk of PG complications, ambulatory status could be a confounding variable. Based on Gross Motor Functioning Classification System (GMFCS), patients were divided into ambulatory (GMFCS I-III) or non-ambulatory (GMFCS IV-V) groupings. We aimed to understand what attributes make NIS patients more susceptible to PG complications compared to their AIS counterparts [5–8].

This study's purpose is to analyze risk factors for PG complications following posterior spinal fusion (PSF) in pediatric NIS patients. We hypothesize that those with greater disease severity, based on ambulation status, would have heightened risk of developing PG complications.

Materials and methods

An IRB-approved retrospective review of pediatric patients (≤ 18 years) who underwent an index spinal fusion for NIS was conducted at two centers. Patients with AIS, adult scoliosis, or revision surgeries were excluded from the original sample. All patients had a minimum of 2-year follow-up. Demographic, radiographic, surgical, and hospital stay data were collected. Subjects were grouped based on the presence or absence of postoperative GI complications (PG vs. NPG) (Fig. 1).

Chronic issues with bowel movement are defined as pre-existing diagnoses prior to surgery. Surgical complications are any postoperative change that required an additional intervention or treatment, irrespective of the fact that it might have existed before surgery. This included issues such as abdominal distention that were not present preoperatively or other complications based on a modified Clavien–Dindo–Sink (CDS) classification system [11]. This CDS classification, with a grading scale between I and V, was used to further stratify complications [11]. Grades I–II were considered minor and Grades III–V were considered major complications (Fig. 2).

Major complications included abdominal compartment syndrome and pneumoperitoneum, while minor complications consisted of abdominal distention, constipation, aspiration, reflux, nausea/vomiting, diarrhea, ileus, GI-infections, or drainage from a gastrostomy tube (G-tube). Distention was defined as a visual or measurable bloated abdomen, accompanied by tympanic sounds following percussion and auscultation. It is measured using a tape measurer or by drawing reference lines on the skin and tracking if distance changes. Distention may occur with or without ileus. Ileus was defined as the near or complete absence of bowel sounds and constipation as a reduction in bowel evacuation with less than three stools a week [12, 13].

Patients were considered to have a PG complication if symptoms began in the immediate postoperative hospital stay period and only if exhibitions spanned over 24 h.

Radiographic parameters included pre- and postoperative major Cobb angle, Cobb correction, and pelvic obliquity. Surgical parameters included levels fused, operative and anesthesia time, and estimated blood loss (EBL). Hospital stay data included length of stay (LOS), first dietary intake, and morphine consumption, which was converted to Morphine Milligram Equivalence (MME).

NIS patients were also divided based on ambulatory status: independent/assisted ambulator (GMFCS I–III) [AMB] and non-ambulatory (GMFCS IV–V) [NAMB]. Patients assigned at a preoperative appointment by the neurologist or orthopedic surgeon. A matched sub-analysis between NIS and AIS patients was conducted. 50 NIS and AIS patients with ≥ 13 levels fused were matched based on age (+/−2), sex, BMI (+/−3), and preoperative Cobb angle (+/−5).

Patient care

As part of standard preoperative protocol, NIS patients undergo gastroenterology, cardiology, and pulmonary clearance with a plan for perioperative GI and pulmonary management. Patients are encouraged to intake fluids 2 h post-surgery. Standardized protocol starts patients on a clear diet on POD0 or POD1, advancing to a regular diet as tolerated.

Ambulation training, if applicable, begins on POD1 under physical therapy and nursing supervision. By POD2, medication and suppositories were given to facilitate bowel

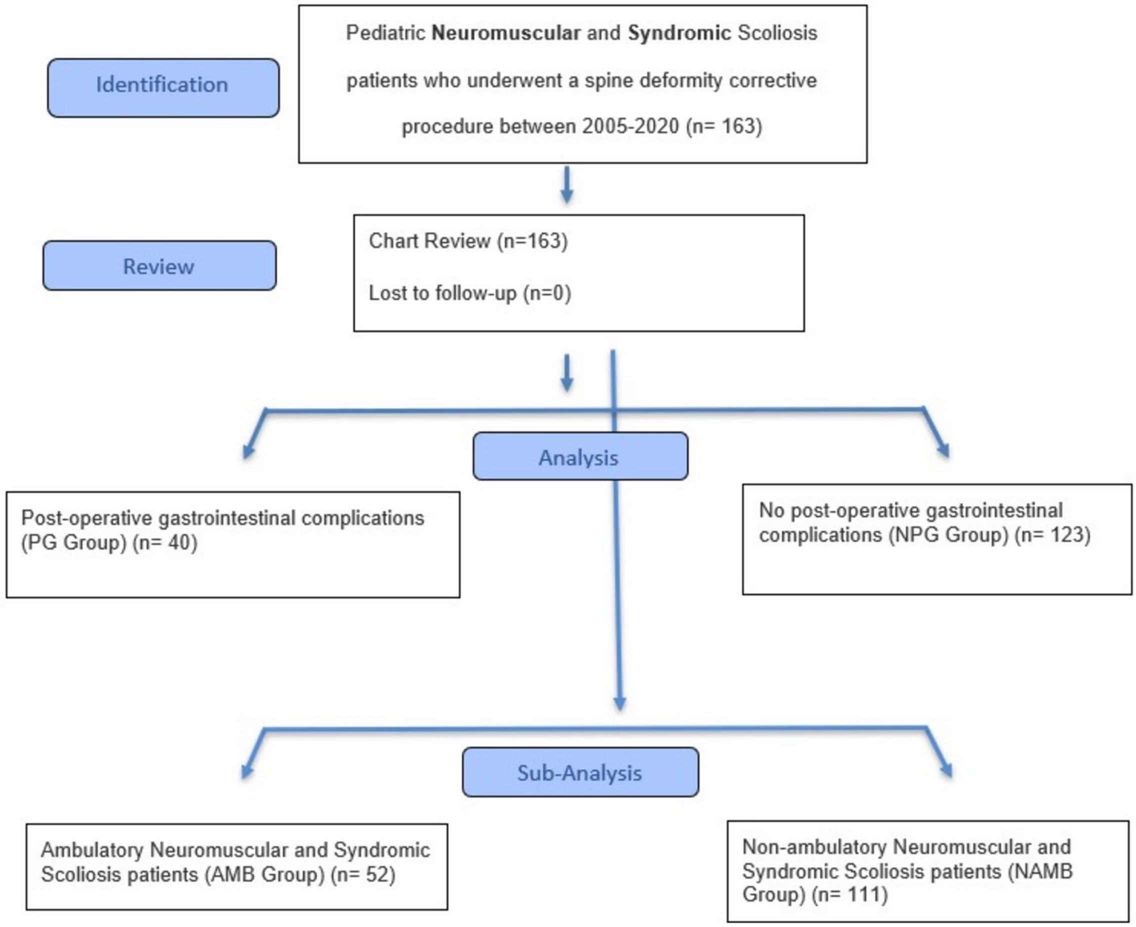

Fig. 1 Patient selection flowchart: neuromuscular and Syndromic Scoliosis Cases

Fig. 2 Modified Clavien–Dindo–Sink classification system

Grade	Definition
I	A complication that does not result in deviation from routine follow-up in the post-operative period and has minimal clinical relevance and requires minimal treatment (e.g. antiemetics, antipyretics, analgesics, diuretics, electrolytes, antibiotics, and physiotherapy) or no treatment.
II	A deviation from the normal postoperative course (including unplanned clinic/office visits) that requires outpatient treatment, either pharmacological or close monitoring as an outpatient, or results in prolonged initial inpatient hospital stay.
III	A complication that is treatable but requires an unplanned hospital readmission; or unplanned surgical, endoscopic, or interventional radiology procedure(s)
IVa	A complication that is life or limb-threatening, and/or requires ICU admission, a complication with potential for permanent disability but treatable, a complication that may require organ/joint resection/replacement. **No long-term disability.**
IVb	A complication that is life or limb-threatening and/or requires ICU admission, a complication that is not treatable, a complication that requires organ/joint resection/replacement or salvage surgery. **With long-term disability.**
V	Death

movements. The protocol is adjusted according to specific patient needs.

Statistical analysis

Differences in demographic and medical characteristics were compared using Wilcoxon rank-sum tests for continuous variables and Chi-squared or Fisher's exact tests for categorical variables. $P<0.05$ is considered statistically significant. Logistic regression was used to examine associations of demographic and medical characteristics with postoperative GI complications. Any variable with $p<0.25$ in initial analysis was a candidate for multiple logistic regression. Only variables that were at 0.05 significance level were retained in the final model. All analyses were performed using SAS software version 9.4 (SAS Inc., Cary, NC) by an independent biostatistician.

Results

Demographics

163 NIS patients were included. Between 2005 and 2020, at two tertiary medical centers, Cerebral Palsy patients ($n=77$, 47.2%) comprised nearly half of the sample. This was followed by syndromic conditions ($n=46$, 28.2%) and other neuromuscular conditions ($n=24$, 14.7%) made up of Duchenne Muscular Dystrophy (6/24, 25%), Spinal Muscular Atrophy (4/24, 16.7%), and others (14/24, 58.3%). Spina bifida ($n=11$, 6.7%) and unidentified neuromuscular conditions ($n=5$, 3.1%) were the smallest groups. Representative conditions of syndromic scoliosis include Rett syndrome (21/46, 45.7%), DiGeorge Syndrome (3/46, 6.5%), and multiple other syndromes, typically by a single case: Marfan's syndrome, Down's syndrome, Prader-Willi syndrome, Charge syndrome, Coffin-Lowry syndrome, Soto syndrome, etc. Patients were included based off ICD-10 codes (Fig. 3).

66 (40.5%) patients had a pre-existing GI comorbidity. 49/66 patients (74.2%) had G-tube present, 33 (50.0%) had GERD, 14 (21.2%) had chronic issues with bowel movements, 3 (4.5%) had previous abdominal operations, and 3 (4.5%) had other GI comorbidities (two chronic colitis and one Barrett's esophagus case). 33 (50.0%) patients were actively followed by a GI specialist within institution (Fig. 4).

40/163 (24.5%) patients experienced 74 total PG complications; 72 minor and 2 major. 39/40 (97.5%) patients developed one or more minor GI complications. There were 31/72 (43.1%) occurrences of distention, 13(18.1%) nausea/vomiting, 10(13.9%) constipation, 4 (5.6%) aspiration, 3 (4.2%) diarrhea, 3(4.2%) G-Tube drainage, 3 (4.2%) ileus, 3 (4.2%) GI infection, and 2 (2.8%) refluxes. 2/40 (5%) patients had a major complication (1 abdominal compartment syndrome and 1 pneumoperitoneum) (Fig. 5). Minor PG complications were stratified by preoperative diagnosis (Fig. 6). Using CDS classification, 28/163 (17.1%) patients experienced Grade I, 10/163 (6.1%) Grade II, 2/163 (1.2%) Grade III, and no Grade IV/V complications.

PG and NPG patients had similar ages ($p=0.47$), BMI ($p=0.30$), and gender distribution ($p=0.67$). PG patients had a higher spastic percentage (72.5% vs. 58.5%, $p=0.11$). Significantly more PG patients were non-ambulatory and had pre-existing GI comorbidities (87.5% vs. 61.8%, $p=0.003$; 75% vs. 29.3%, $p<0.001$) (Table 1).

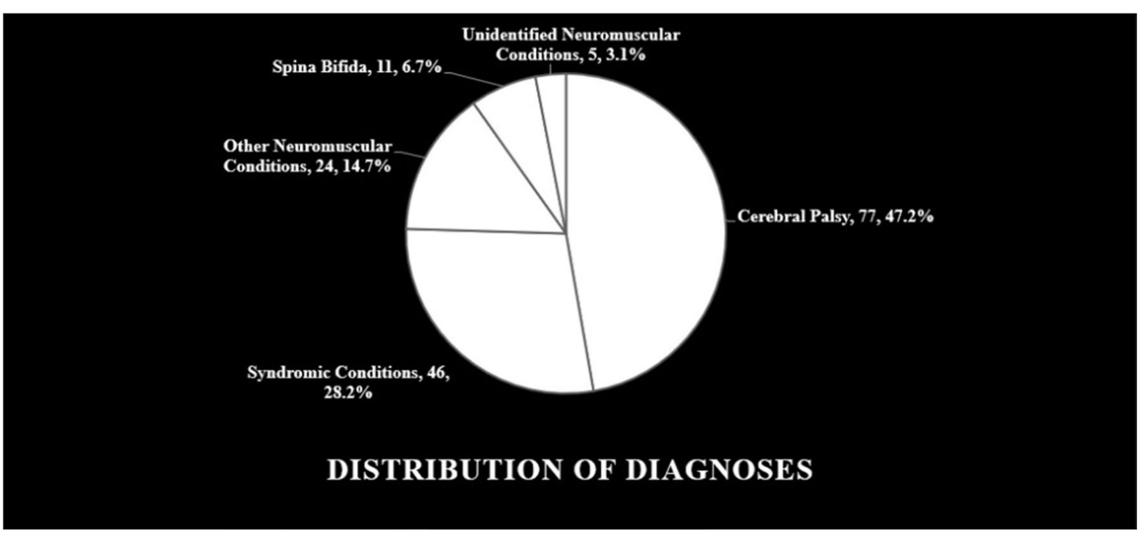

Fig. 3 Pie Chart distribution of preoperative diagnoses

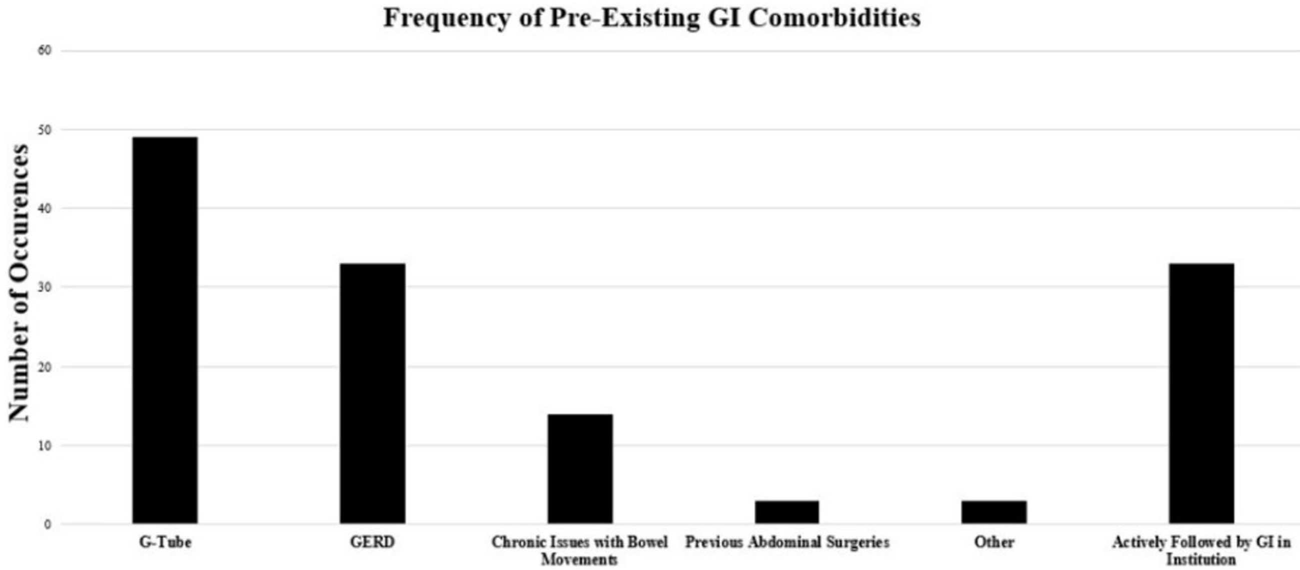

Fig. 4 Frequency distribution of preoperative GI comorbidities. There were sixty-six patients with preoperative GI comorbidities; however, some patients presented with multiple comorbidities

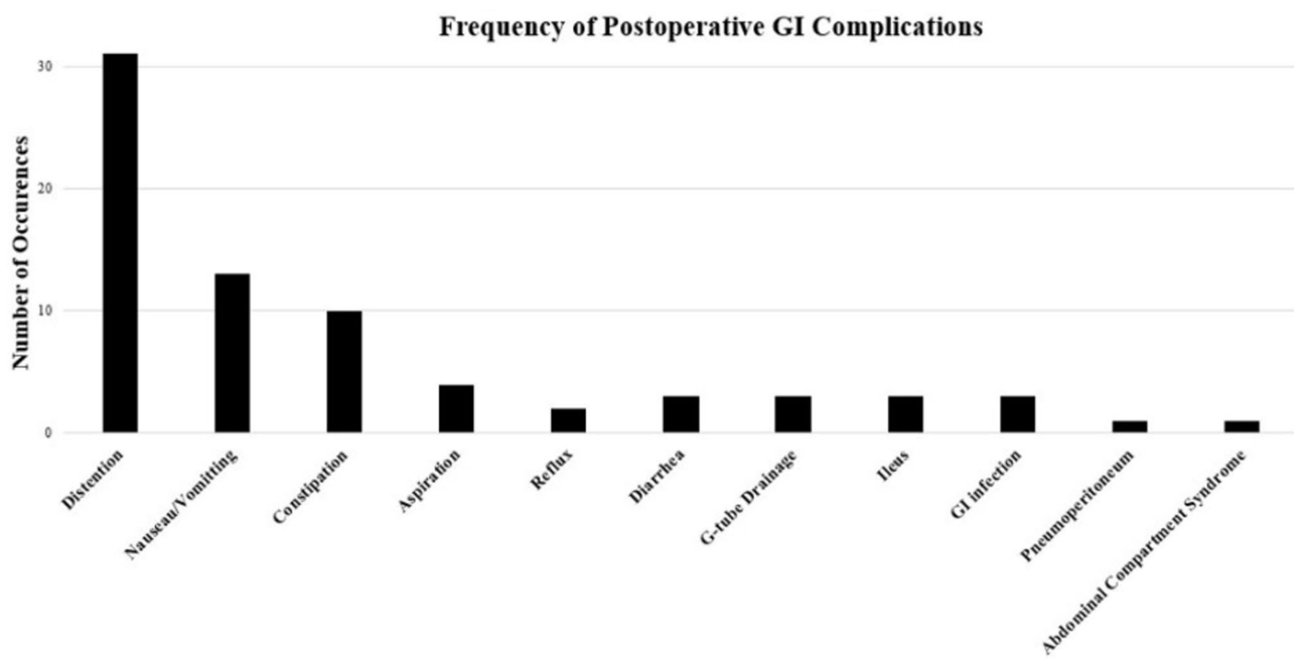

Fig. 5 Frequency of postoperative GI complications. A majority of patients had multiple minor postoperative GI complications. Two patients each suffered one major postoperative GI complication

Clinical outcomes

PG patients had significantly larger preoperative major Cobb (79.0° vs. 64.2°, $p=0.002$), postoperative major Cobb (40.0° vs. 22.0°, $p<0.001$), and smaller Cobb correction (48.3% vs. 66.4%, $p<0.001$). Pelvic obliquity was also higher in PG patients preoperatively and postoperatively compared to NPG patients (15.4° vs. 7.8°, $p=0.01$; 12.4° vs. 4.6°, $p<0.001$). PG and NPG had a median 16.0 levels fused ($p=0.23$).

No significant differences in operative, anesthesia, and first oral intake times between groups. EBL (600.0 mL vs. 725.0 mL, $p=0.11$) and median LOS (9.0 days, $p=0.65$) were comparable. PG and NPG patients had similar

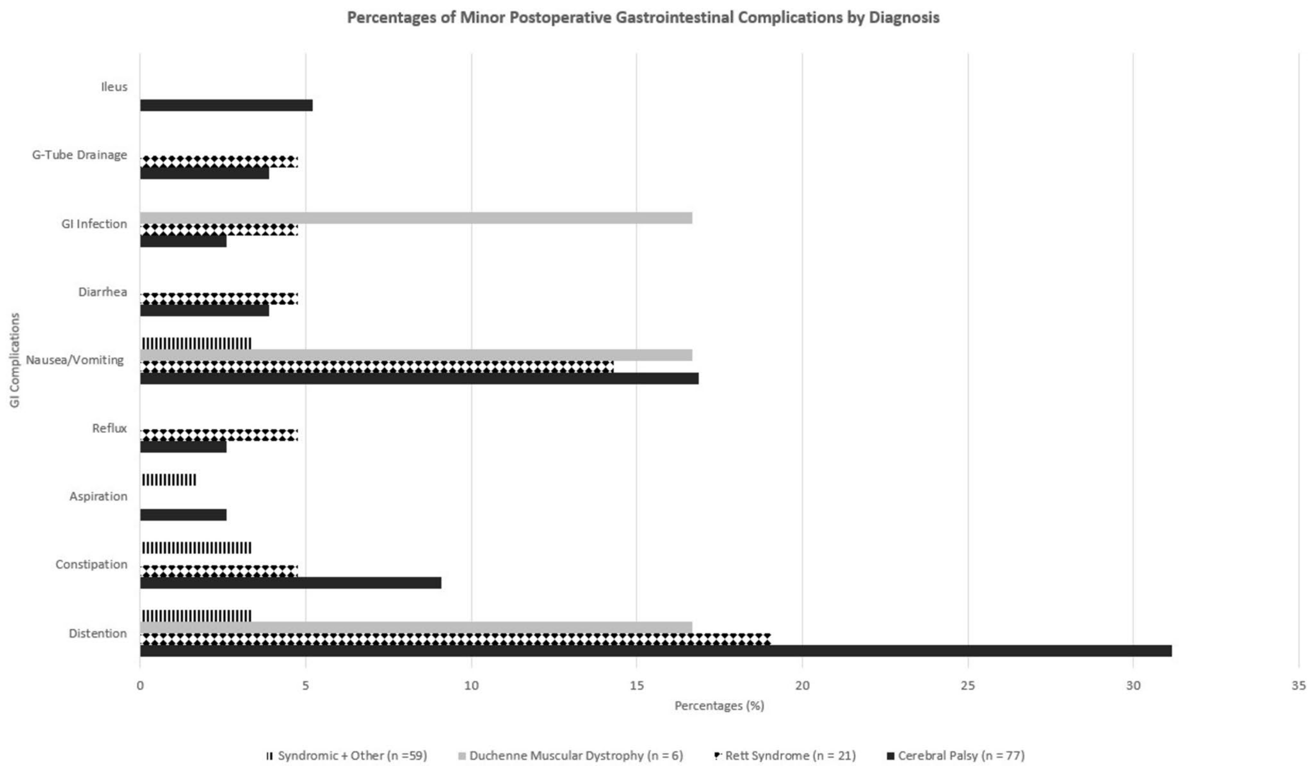

Fig. 6 Percentages of GI complications by preoperative diagnosis. Some patients experienced more than one complication. Percentages here are shown relative to the diagnosis group

intraoperative and 0–48-h postoperative morphine consumption ($p=0.64$, $p=0.56$) (Table 1).

Complications

30 non-GI complications within 30 days of hospital discharge: 8 (20.0%) PG and 22 (17.9%) NPG patients ($p=0.76$). PG group complications included three surgical site infections (SSIs), one superficial wound dehiscence, one urinary tract infection (UTI), one severe seizure, one persistent fever, and one patient experienced fever and vomiting. Of the 3 SSIs, one patient developed *Clostridioides difficile* and two experienced loose stools. All patients underwent incision and drainage with washout and primary closure. None required wound VAC (Vacuum-Assisted Closure) or a repeat procedure. In the NPG group, there were four SSIs requiring debridement and washout (one required implant removal), five UTIs, three pneumonia cases, three atelectasis cases, and one case of hypovolemic shock.

Ambulatory status

52 patients were classified as AMB (GMFCS I-III), and 111 patients were classified as NAMB (GMFCS IV-V). No significant demographic differences were found. Preoperative and postoperative Cobb angles, pelvic obliquity, Cobb correction, and levels fused were significantly lower in the AMB group ($p<0.05$). Pre-existing GI comorbidities were significantly lower in the AMB group (9.6% vs. 55.0%, $p<0.001$). AMB patients had significantly lower EBL (600.0 mL vs. 755.0 mL, $p=0.02$), transfusion-rate (57.7% vs. 84.7%, $p<0.001$), operative time (301.0 min vs. 380.5 min, $p<0.001$), anesthesia time (444.5 min vs. 545.0 min, $p<0.001$), and LOS (7.0 days vs. 11.0 days, $p<0.001$) than NAMB patients. Intraoperative and 0–48-h morphine consumption was not statistically different ($p=0.97$, $p=0.82$). AMB group experienced significantly fewer in-hospital GI complications (9.7%vs.31.5%, $p=0.003$) and non-GI complications within 30 days (5.8% vs. 24.3%, $p=0.004$). Non-GI complications between 31 and 90 days were comparable ($p=0.18$) (Table 2).

Matched analysis: NIS vs. AIS

No significant differences between groups for non-GI 30-day ($p=0.53$) and 31–90-day complications ($p=0.48$). NIS patients required significantly more transfusions ($p<0.001$), had more pre-existing GI comorbidities ($p<0.001$), and experienced more GI complications ($p=0.02$) compared to AIS patients (Table 3).

Table 1 Comparison of demographic, radiographic, surgical, and clinical variables between PG patients (with postoperative GI complications) and NPG (without postoperative GI complications)

	PG ($n=40$)	NPG ($n=123$)	p value
Age	13.9 (11.2–16.2)	14.0 (11.9–16.4)	0.47
BMI (kg^2/m)	18.7 (15.7–20.8)	18.2 (16.6–22.8)	0.30
Female, n (%)	24 (60.0%)	69 (56.1%)	0.67
Spasticity, n (%)	29 (72.5%)	72 (58.5%)	0.11
Pre-existing GI comorbidities, n (%)	30 (75.0%)	36 (29.3%)	**< 0.001**
Preoperative cobb (°)	79.0 (65.5–91.9)	64.2 (51.4–81.4)	**0.002**
Postoperative cobb (°)	40.0 (28.3–48.5)	22.0 (13.2–36.9)	**< 0.001**
Cobb correction (%)	48.3 (30.4–63.5)	66.4 (49.8–76.4)	**< 0.001**
Levels fused	16.0 (15.0–17.0)	16.0 (14.0–17.0)	0.23
Preoperative pelvic obliquity (°)	15.4 (5.6–21.5)	7.8 (2.9–17.5)	**0.01**
Postoperative pelvic obliquity (°)	12.4 (3.8–21.9)	4.6 (1.8–9.7)	**< 0.001**
Ambulatory status			**0.003**
GMFCS I–III	5 (12.5%)	47 (38.2%)	
GMFCS IV–V	35 (87.5%)	76 (61.8%)	
Operative time (mins)	338.0 (279.0–401.0)	365.0 (283.0–470.0)	0.21
Anesthesia time (mins)	524.0 (447.0–616.0)	525.0 (433.0–600.0)	0.73
EBL (mL)	600.0 (300.0–1200.0)	725.0 (500.0–1000.0)	0.11
Transfusion, n (%)	30 (75.0%)	95 (77.2%)	0.77
Time to food (h)	43.8 (27.9–77.4)	40.0 (27.1–77.5)	0.82
Length of stay	9.0 (6.0–25.0)	9.0 (7.0–15.0)	0.65
ICU stay	4.0 (2.0–14.0)	4.0 (3.0–5.0)	0.09
Intraoperative morphine equivalence (mg)	39.2 (23.9–65.1)	41.2 (25.0–65.0)	0.64
0–48 h postoperative morphine equivalence (mg)	86.8 (52.0–194.0)	91.0 (37.5–135.9)	0.56
Non-GI complications within 30 days, n (%)	8 (20.0%)	22 (17.9%)	0.76

$p < 0.05$ is considered statistically significant and are bolded

p values were obtained from Wilcoxon rank-sum tests for continuous variables, and Chi-square or Fisher's exact tests for categorical variables

Matched analysis: ambulatory NIS vs. AIS

Of the 50 pairs of NIS and AIS patients, 16 included exclusively ambulatory patients, showing no differences in pre-existing GI comorbidities ($p=$ n/a) or PG complications ($p=1.0$) (Table 4).

Risk factors: logistic regression analysis

Multivariable logistic regression showed pre-existing GI comorbidity patients (OR = 5.34, 95% CI 2.03–14.03; $p < 0.001$) had higher odds of PG complications. Within the pre-existing GI comorbidities, patients with a pre-existing G-tube (OR = 3.02, 95% CI 1.25–7.29; $p=0.02$) or actively followed by GI in institution (OR = 6.23, 95% CI 2.43–15.95; $p < 0.001$) were more likely to have PG complications. Higher postoperative Cobb angle (OR = 1.05, 95% CI 1.02–1.08; $p=0.001$) or patients with higher postoperative pelvic obliquity (OR = 1.11, 95% CI 1.04–1.18; $p=0.001$) were statistically associated with increased odds of PG complication.

Discussion

In the present study, the incidence of postoperative GI complications, within a non-idiopathic population, was 24.5%, similar to the referenced studies [7, 14, 15]. Jalanko et al. reported a 13% rate in NIS patients, while Gabos et al. found major GI complications occurred in 37% of patients [7, 15]. In our study, we found most GI complications to be primarily minor. Of the 74 total occurrences, 72 (97.3%) were minor and 2 (2.7%) were major; these two being abdominal compartment syndrome and pneumoperitoneum. Furthermore, 70% of complications were CDS Grade I, with no Grade IV/V. This consisted most frequently of distention, constipation, or other adverse events which did not result in deviations from routine postoperative precautions. For example, many resolve with diuretics, electrolytes, or antibiotics and in some cases no additional treatment at all.

Although both PG and NPG had a median LOS of 9.0 days, the complications themselves do not appear to influence LOS. Patients who experienced prolonged stays are likely due to other factors. In some cases, complications did delay feeding, resulting in either NPO directions

Table 2 Comparison of radiographic, surgical, and clinical variables between ambulatory (AMB) and non-ambulatory (NAMB) NIS patients

	AMB ($n=52$)	NAMB ($n=111$)	p value
Preoperative cobb (°)	60.1 (47.1–70.0)	73.0 (60.0–87.7)	**< 0.001**
Postoperative cobb (°)	20.0 (11.3–27.7)	32.5 (17.9–43.7)	**< 0.001**
Cobb correction (%)	48.2 (30.8–63.8)	61.4 (47.17–3.8)	**0.005**
Female, *n* (%)	30 (57.7%)	63 (56.7%)	0.91
Levels Fused	14.0 (13.0–16.0)	16.0 (15.0–17.0)	**0.001**
Preoperative pelvic obliquity (°)	3.3 (1.7–7.0)	15.1 (5.9–22.2)	**< 0.001**
Postoperative pelvic obliquity(°)	2.6 (1.0–5.8)	9.2 (3.3–15.3)	**< 0.001**
Pre-existing GI comorbidities, *n* (%)	5 (9.6%)	61 (55.0%)	**< 0.001**
EBL (mL)	600.0 (400.0–850.0)	755.0 (500.0–1300.0)	**0.02**
Anesthesia time (mins)	444.5 (405.0–545.5)	545.0 (476.0–625.0)	**< 0.001**
Operative time (mins)	301.0 (261.0–393.0)	380.5 (319.5–470.0)	**< 0.001**
Length of stay	7.0 (5.0–10.0)	11.0 (7.0–19.0)	**< 0.001**
Total transfusions, *n* (%)	30 (57.7%)	94 (84.7%)	**< 0.001**
Intraoperative morphine (mg)	43.1 (28.0–70.0)	42.5 (25.0–75.0)	0.97
0–48 h postoperative morphine consumption (mg)	106.5 (68.3–150.2)	86.2 (48–194.7)	0.82
GI complications in-hospital, *n* (%)	5 (9.7%)	35 (31.5%)	**0.003**
Non-GI complications within 30 days, *n* (%)	3 (5.8%)	27 (24.3%)	**0.004**
Non-GI complications within 31–90 days, *n* (%)	0 (0.0%)	5 (4.5%)	0.18

$p < 0.05$ is considered statistically significant and are bolded

p values were obtained from Wilcoxon rank-sum tests for continuous variables, and Chi-square or Fisher's exact tests for categorical variables

Table 3 Matched comparison of categorical clinical and surgical variables between non-idiopathic scoliosis (NIS) and adolescent idiopathic scoliosis (AIS) patients with ≥ 13 levels fused

	[a]Concordance with effect	[b]Concordance without effect	[c]Discordance with effect	[d]Discordance without effect	*p value
Total transfusions	4	9	34	3	**< 0.001**
Pre-existing GI comorbidities	2	32	16	0	**< 0.001**
GI complications in-hospital	1	34	12	3	**0.02**
Non-GI complications within 30 days	1	36	6	4	0.53
Non-GI Complications within 31–90 days	0	40	3	5	0.48

50 AIS patients were matched to 50 NIS patients on age (± 2), sex, BMI (± 3), preoperative Cobb angle (± 5°)

$p < 0.05$ is considered statistically significant and are bolded

*p values were obtained from McNemar's tests

[a]Concordance with effect: both matched patients experienced the outcome

[b]Concordance without effect: both matched patients did not experience the outcome

[c]Discordance with effect: only the NIS patient experienced the outcome

[d]Discordance without effect: only the AIS patient experienced the outcome

and/or IV fluids being administered (16/38, 42.1%). The majority of patients in both groups exhibited other comorbidities that are likely the cause of prolonged hospital stay more than GI complications alone. Some of these comorbidities include epilepsy and other seizure disorders, infections, chronic respiratory failure, pleural effusion, and restrictive lung disease. While the majority of GI complications resolved in 4–5 days, extended LOS is associated with other underlying medical conditions. This shows that patients can experience an extended LOS both with and without a PG complication, but not as a result of a PG complication. 18/40 patients (45%) in the PG group had an extended length of stay greater than 9.0 days. In contrast, 60/123 (48.8%) NPG patients stayed longer than 9.0 days. In both groups, patients experienced other non-GI complications in-hospital. Based on previous literature, Sharma et al. and Tandevold et al. have shown a median LOS between 9.0 and 11.0 days, which followed a

Table 4 Matched comparison of categorical clinical variables in ambulatory patients (GMFCS I-III) with ≥ 13 levels fused

	[a]Concordance with effect	[b]Concordance without effect	[c]Discordance with effect	[d]Discordance without effect	*p value
Pre-existing GI comorbidities	0	15	1	0	n/a
GI complications in-hospital	0	12	2	2	1.0

16 adolescent idiopathic scoliosis (AIS) patients were matched to 16 non-idiopathic scoliosis (NIS) patients on age (±2), sex, BMI (±3), preoperative Cobb angle (±5°)

$p < 0.05$ is considered statistically significant and are bolded

*p values were obtained from McNemar's tests

[a]Concordance with effect: both matched patients experienced the outcome

[b]Concordance without effect: both matched patients did not experience the outcome

[c]Discordance with effect: only the NIS patient experienced the outcome

[d]Discordance without effect: only the AIS patient experienced the outcome

pre-ERAS protocol [16, 17]. Similarly, most of the study's patients are pre-ERAS, aligning with other literature.

Another finding revealed no significant difference in intraoperative or 0–48-h morphine consumption between PG and NPG patients. Opioids impact GI motility, but unlike Jalanko et al., no difference was found in opioid consumption between groups [7]. This may be due to standardized pain protocols at our institution. In 2018, a Rapid Recovery Pathway (RRP) protocol was implemented, prioritizing perioperative opioid education to patients and family members. It utilizes a microdose of intrathecal morphine intraoperatively to provide the patient with adequate pain control throughout recovery and lowers postoperative opioid consumption. Patients are given oral opioids and IV for breakthrough pain, while patient-controlled-analgesia is eliminated [16]. This standardized pain protocol, overseen and controlled by a dedicated team, minimizes duration, dosage, and reliance on intravenous opioids.

Prior to 2018, our standard protocol included Patient-Controlled Analgesia (PCA) or Nurse-Controlled Analgesia(NCA) which provided patients with an opioid pump, allowing up to 1 mg of opioids per hour for a maximum of 48-h postoperatively, then transitioning to oral medications [18]. This contrasts with Jalanko et al. where patients with increased postoperative GI complications were seen with IV medications for 5 days, a long duration of administering opioids and different from our standard of care. Furthermore, patients stayed longer, even those without GI complications, a median of 16 vs. 22 days [7].

Our RRP protocol provides patients with effective pain management throughout recovery while eliminating the need for PCA entirely and likely explains nonsignificant differences between opioid dosage in those with or without GI complications. The further decrease in opioid amount allows for similar return of GI motility.

In our study, larger Cobb angle and pelvic obliquity were found to be associated with PG complications. Jalanko et al. identified larger preoperative Cobb angle as a risk factor for GI complications [7]. On multivariate logistic regression analysis, postoperative Cobb angle and postoperative pelvic obliquity had odds ratios of 1.05 and 1.11, respectively. These findings, although statistically significant, may not be clinically relevant.

This study found pre-existing GI diseases to have greater odds of postoperative GI complications. On a multivariable logistic regression analysis, the most important factor was pre-existing GI comorbidities, which increased surgical risk by 5.34x. Having a pre-existing G-tube and being actively followed by GI specialists were also significant risk factors for PG complications (by 3.02x and 6.23x, respectively). This indicates a more involved comorbidity that has not yet reached a resolution places patients at higher risk. Nishnianidze et al. and Verhofste et al. noted G-tube dependence as a risk factor for complications after PSF in cerebral palsy patients [8, 9]. Pre-existing swallowing difficulties, G-tube presence, and gastric reflux disease have been shown in various studies as risk factors for postoperative GI complications [8, 9, 19].

Approximately, 90% of patients with PG complications were non-ambulatory, and 55% had pre-existing GI comorbidities, which is significantly higher than the ambulatory patients. 31% of non-ambulatory patients experienced a PG complication, compared to < 10% of the ambulatory patients. Non-ambulatory patients had significantly higher EBL, levels fused, transfusion-rates, and prolonged operative and anesthesia times. However, these variables were not significant between patients with or without PG complications. Verhofste et al. found greater EBL in NMS patients with GI complications, while Jalanko et al. saw no difference [7, 8]. Such factors are more likely an outcome of surgery due to increased levels fused and larger deformity in non-ambulatory patients [6].

Non-ambulatory status itself appears to be a surrogate for increased complications, including GI. This was further evident on a matched sub-analysis between ambulatory NIS and AIS pairs, showing no significant differences in pre-existing GI comorbidities and postoperative GI complications. Ambulatory NIS patients seem to behave similar to AIS patients [4].

These findings that non-ambulatory status, larger curves, greater pelvic obliquity, G-tube presence, and GI follow-up are associated with increased odds of postoperative GI complications reflect disease severity. The retrospective design of this study, the duration of the study, two institutions versus multi-institutions, and varying spectrum of disorders reviewed are limitations. However, this is a large study over a long period in two different institutions with rigorously matched statistical analysis, reducing confounding variables. This study finds that in most NIS patients, PG complications are frequent but do not impact patient outcomes.

Conclusion

The severity of underlying disease in NIS patients influences need for treatment. Surgical teams need to be cognizant of pre-existing GI comorbidities, having a G-tube present, or being actively followed by a GI specialist, as those are the most significant and relevant risk factors for postoperative GI complications.

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Data availability Datasets generated and analyzed during the current are not publicly available but are available from the corresponding author on reasonable request.

Declarations

Conflict of interest Dr. Sarwahi received personal fees from Medical Device Business Services, INC., personal fees from Depuy Synthes, INC, personal fees from Precision Spine, INC., personal fees from Nuvasive, INC., outside the submitted work. All other authors declare they have no relevant financial or non-financial interests and no conflicts of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent This research study was conducted retrospectively from data obtained for clinical purposes. We consulted extensively with the IRB of Northwell Health who determined that our study did not need ethical approval. An official waiver of ethical approval was granted from the IRB of Northwell Health.

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