Received: 21 March 2024 | Revised: 25 August 2024 | Accepted: 23 September 2024

DOI: 10.1111/pan.15019

Pediatric Anesthesia WILEY

RESEARCH REPORT

Intravenous lidocaine infusion therapy and intraoperative neurophysiological monitoring in adolescents undergoing idiopathic scoliosis correction: A retrospective study

Rachel Bates[1,2] | Fiona Cave[3] | Nicholas West[1,2] | Jeffrey N. Bone[2] | Bradley Hofmann[4] | Firoz Miyanji[2,5,6] | Gillian R. Lauder[1,2,4]

[1]Department of Anesthesia, British Columbia Children's Hospital, Vancouver, British Columbia, Canada

[2]Research Institute, British Columbia Children's Hospital, Vancouver, British Columbia, Canada

[3]Department of Neurodiagnostics, Kelowna General Hospital, Kelowna, British Columbia, Canada

[4]Department of Anesthesiology, Pharmacology, and Therapeutics, University of British Columbia, Vancouver, British Columbia, Canada

[5]Department of Orthopaedics, University of British Columbia, Vancouver, British Columbia, Canada

[6]Department of Orthopaedics, British Columbia Children's Hospital, Vancouver, British Columbia, Canada

Correspondence
Gillian R. Lauder, British Columbia Children's Hospital, 4480 Oak Street, Vancouver, BC V6H 3V4, Canada.
Email: glauder@cw.bc.ca

Funding information
Biotalent Canada; BC Children's Hospital Research Institute

Section Editor: Nada Sabourdin

Abstract

Background: Posterior spinal instrumentation and fusion is an established surgical procedure for the correction of adolescent idiopathic scoliosis. Intraoperative neurophysiological monitoring is standard practice for this procedure. Anesthetic agents can have different, but significant, effects on neurophysiological monitoring outcomes.

Aim: To determine if intravenous lidocaine infusion therapy has an impact on the intraoperative neurophysiological monitoring during posterior spinal instrumentation and fusion for adolescent idiopathic scoliosis.

Methods: Following ethical approval, we conducted a retrospective review of charts and the archived intraoperative neurophysiological data of adolescents undergoing posterior spinal instrumentation and fusion for adolescent idiopathic scoliosis. Intraoperative neurophysiological monitoring data included the amplitude of motor evoked potentials and the amplitude and latency of somatosensory evoked potentials. A cohort who received intraoperative lidocaine infusion were compared to those who did not.

Results: Eighty-one patients were included in this analysis, who had surgery between February 4, 2016 and April 22, 2021: 39 had intraoperative intravenous lidocaine infusion and 42 did not. Based on hourly snapshot data, there was no evidence that lidocaine infusion had a detrimental effect on the measured change from baseline for MEP amplitudes in either lower (mean difference 41.9; 95% confidence interval −304.5 to 388.3; $p = .182$) or upper limbs (MD −279.0; 95% CI −562.5 to 4.4; $p = .054$). There was also no evidence of any effect on the measured change from baseline for SSEP amplitudes in either lower (MD 16.4; 95% CI −17.7 to 50.5; $p = .345$) or upper limbs (MD −2.4; 95% CI −14.5 to 9.8; $p = .701$). Finally, there was no evidence of a difference in time to first reportable neurophysiological event (hazard ratio 1.13; 95% CI 0.61 to 2.09; $p = .680$).

Conclusions: Data from these two cohorts provide preliminary evidence that intravenous lidocaine infusion has no negative impact on intraoperative neurophysiological monitoring during PSIF for adolescent idiopathic scoliosis.

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.
© 2024 The Author(s). *Pediatric Anesthesia* published by John Wiley & Sons Ltd.

KEYWORDS
adolescent idiopathic scoliosis, intraoperative neurophysiological monitoring, intravenous lidocaine infusion, posterior spinal instrumentation and fusion

1 | INTRODUCTION

Posterior spinal instrumentation and fusion is a common surgical procedure for correction of adolescent idiopathic scoliosis. It is a major surgical insult that can be associated with significant postoperative pain.[1] Multimodal analgesia is utilized perioperatively to help prevent and manage this pain. It is important to minimize the requirements for any individual analgesic modality to minimize their potential side effects.[2,3] This is especially true for opioids, which have a dose-dependent side effect profile.[4] Lidocaine has been used as a peri-operative adjuvant to multimodal analgesia to help improve postoperative pain and minimize opioid requirements.[5–7] Its efficacy and safety have been established in adults.[8]

Intraoperative neurophysiological monitoring (IONPM) is standard of care for PSIF procedures.[9] It involves the integration of somatosensory evoked potentials (SSEPs), transcranial motor evoked potentials (MEPs), electroencephalogram (EEG), and electromyography (EMG). IONPM helps to ensure the integrity of the motor and sensory spinal cord pathways and issues alerts in the event of potential spinal cord impairment, allowing for intervention to mitigate injury progression or reversal of potential neurological sequelae. Anesthetic agents can have significant effects on IONPM; for instance, inhalational agents adversely affect SSEPs and MEPs, and muscle relaxants can impact MEPs and EMG.[10,11]

While there is limited data on adolescents, adult studies have reported reduced amplitude and increased latency of SSEP responses in patients receiving intraoperative lidocaine infusion when undergoing abdominal or orthopedic surgery[12] and absent or reduced SSEP amplitudes following lidocaine administration in scoliosis surgery.[13]

The aim of this study was to investigate whether intraoperative intravenous lidocaine infusion therapy (I-IVLT) has any impact on the reliability of IONPM monitoring in adolescents undergoing PSIF for idiopathic scoliosis, principally to support the continued use of lidocaine infusion therapy as an adjunct to multimodal analgesia without compromising patient safety. Specifically, we aimed to evaluate the evidence for any differences in hourly-sampled measurements of MEP amplitude, SSEP amplitude and SSEP latency, for both upper and lower limbs, in adolescent patients receiving an intraoperative lidocaine infusion during PSIF surgery compared with a similar cohort, who did not receive lidocaine. We also aimed to evaluate any differences in the number of reportable neurophysiological events, based on clinical alert criteria for acceptable deviation of these measurements from baseline, or time to first event.

2 | METHODS

2.1 | Study design

We conducted a single-centre retrospective review of PSIF procedures for adolescent idiopathic scoliosis, comparing a cohort of cases in which lidocaine was infused intraoperatively with a similar cohort in which no lidocaine was given. Electronic records were reviewed for relevant anesthetic and surgical information, including which patients received I-IVLT. IONPM data were retrieved from archived data held within the neurophysiology department for each patient. The study was approved by the University of British Columbia/Children's and Women's Health Centre of British Columbia Research Ethics Board (H20-01875), including waiver of the requirement for informed consent. This manuscript has been prepared in accordance with the STROBE guidelines.[14]

2.2 | Setting and participants

Patients were included if they underwent single-stage PSIF with or without traction for adolescent idiopathic scoliosis corrective surgery at BC Children's Hospital, a tertiary care academic pediatric facility. The study period spanned January 2012 to April 2021. Eligibility criteria included American Society of Anaesthesiologists (ASA) status I–III, ages 10–19. Cases were excluded if surgery was more than a single-stage procedure, if the surgical technique comprised of an anterior, thorascopic, or tethering approach, or if patients had a neuromuscular or congenital cause for scoliosis. All included patients received standard IONPM.

Charts were reviewed to distinguish cases with I-IVLT administration from those without. I-IVLT was given as a 1 mg/kg bolus followed by and infusion of 2 mg/kg/h. until the end of the surgical procedure; this I-IVLT regimen has been applied consistently across the study period.

2.3 | IONPM procedures

IONPM was performed using current practice standards and organizational protocols, by experienced technologists certified in Neurophysiological Intraoperative Monitoring (Appendix A). The monitoring device changed from the Cascade PRO, used 2012–2019, to the Cascade IOMAX, used 2019–2021 (Cadwell Industries Inc., Kennewick, WA), but there were no changes in the monitoring protocol or the parameters used for event reporting during the study period.

2.4 | Variables collected and data sources

For all patients included in this analysis, recorded demographic data included: ASA status, age, height, weight, sex, allergies, Lenke curve, Cobb angle, details of the surgical procedure (number of vertebral levels fused, number of vertebrectomies, presence of surgical duration of traction traction), and confirmation of I-IVLT or not.

IONPM data included the amplitude and latency of the SSEP responses bilaterally from both the ulnar and post tibia evoked potentials and the amplitudes of the MEPs, and were collected from the neurophysiological records. Baseline values for these measurements were taken after induction of anesthesia, and after commencement of the I-IVLT if given, but prior to the start of surgery. The entire case was reviewed and neuromonitoring variables were sampled and recorded at approximately one hourly intervals at which the required data were available, and recorded as measured changes from these baseline values. The completeness of clinical neurophysiological data at other timepoints that were not required for the study was not evaluated.

For MEPs, bilateral adductor pollicis brevis and brachoradialis muscles were aggregated into upper limbs; and bilateral adductor hallucis and tibialis anterior muscles were aggregated into lower limbs. SSEP measurements were also reported as upper limbs (bilateral ulnar nerves) and lower limbs (bilateral posterior tibial nerves). Reported outcomes include: MEP amplitude for lower limbs and upper limbs; SSEP amplitude for lower limbs and upper limbs; and SSEP latency for upper and lower limbs (Figure 1).

IONPM events were identified by reviewing neuromonitoring data for any changes that reached clinical alert criteria of a reduction in amplitude of ≥50% in MEPs or SSEPs, or an SSEP latency increase of ≥10%. Factors associated with IONPM, such as mean arterial blood pressure (MAP), Bispectal index (BIS), temperature, and heart rate were documented when available in the neurophysiological records, along with details of any additional medication boluses.

De-identified data were recorded in a Research Education Data Capture (REDCap) database.[15]

2.5 | Data analysis

2.5.1 | Sample size

We had an available sample of 39 cases in which I-IVLT had been used as part of the anesthetic regimen. We selected an additional sample of 42 cases, in which I-IVLT had not been used by searching the neurophysiology database for eligible cases managed by anesthesiologists who do not incorporate I-IVLT into their practice, starting at the end-date of our study period and working backwards until we had an equal number of cases; we collected an additional three cases in case of missing data. All cases were selected before IONPM data were reviewed.

2.5.2 | Statistical analysis and quantitative variables

Differences in age, sex, weight, Cobb angle, surgical duration, and number of vertebral levels fused between the group that received I-IVLT and the group that did not were evaluated based on a standardized mean difference calculated using Cohen's *h* for the binary variable (sex) and Cohen's *d* for the continuous variables. For hourly snapshot data, we used a linear mixed effects model, including fixed effects for surgical time elapsed and administration of intraoperative lidocaine or not, with participant as a random effect. Data were compared between two groups: cases who received I-IVLT versus cases who received no lidocaine infusion; between

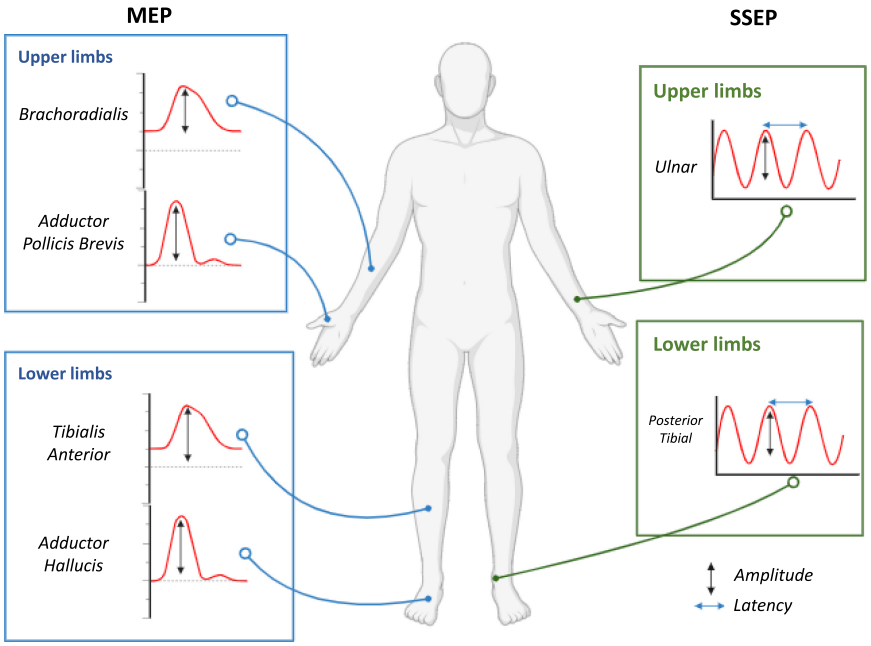

FIGURE 1 Infographic showing motor-evoked potential (MEP) and somatosensory evoked potential (SSEP) anatomical measurement points and resulting waveforms.

TABLE 1 Demographic and procedure data.

Demographic	Lidocaine group ($n=39$)	No Lidocaine group ($n=42$)	Standardized mean difference
Age (years)	14.0 (12.2, 15.0)	13.5 (11.2, 15.8)	0.174
Sex: Female	30 (77%)	30 (71%)	0.175
Weight (kg)	54.0 (50.0, 60.0)	53.5 (49.2, 65.5)	0.034
Cobb angle (°C)	55.0 (48.0, 65.0)	52.5 (45.5, 65.0)	0.089
Surgery duration (hours)	5.4 (4.7, 6.5)	5.2 (4.2, 6.5)	0.168
Number of vertebral levels fused	10 (7, 12)	10.5 (7, 12)	−0.157

Note: Data represented as median (interquartile range) for continuous measures or *n* (%) for counts; standardized mean difference calculated using Cohen's *h* for the binary variable (sex) and Cohen's *d* for the continuous variables.

group results are reported using mean difference (MD) and their 95% confidence interval (CI). Hourly snapshot data are displayed in box plots. We also examined the effect of the elapsed surgical duration on MEP and SSEP measurements in terms of stabilizing or destabilizing effect (associated with a deviation from baseline as procedure time increases). In other words, whether increasing elapsed surgical time is associated with a deviation of or conformity to baseline values.

We compared the total number of reportable neurophysiological events using Fishers exact test and used a Kaplan–Meier survival curve and hazard ratios, estimated from a Cox proportional hazards model, to represent time to first reportable event in each group. Reportable events were operationalized in accordance with clinical alert criteria as a 10% increase in SSEP latency or a 50% decrease in SSEP or MEP amplitude.[16]

Exploratory noninferiority testing was also completed on hourly snapshot data using the above reportable event criteria of 10% for SSEP latency and 50% for SSEP or MEP amplitude as a clinical significance margin.[17] All statistical analyses were conducted in R v4.3.0.[18]

3 | RESULTS

3.1 | Participants

Data were available from 81 cases conducted between 4 February 2016 and 22 April 2021: 39 cases in the group who received I-IVLT and 42 cases in the group who received no lidocaine infusion; differences in demographic and procedure characteristics between groups were small (Table 1). All participants received propofol-opioid total intravenous anesthesia (TIVA). Baseline MAP was higher in the I-IVLT group compared to the no lidocaine group (MD 6, 95% CI 0 to 11; $p=.044$), but there were no differences between the groups in baseline MEP, SSEP, BIS or body temperature measurements and no differences between the groups in subsequent hourly intraoperative measurements for BIS, MAP, or body temperature throughout the surgery (Table 2).

3.2 | Hourly neurophysiological monitoring

IONPM measurements of MEP amplitude and SSEP amplitude and latency for both upper and lower limbs were available for all participants at baseline. We had a total of 385 hourly snapshot data points across all participants, with a median (interquartile range) of 5.0 (4.0–5.5) hourly data points per participant in the I-IVLT group and 5.0 (4.0–5.8) in the no lidocaine group. For each snapshot data point, we had full data for MEP (amplitude) and SSEP (amplitude and latency) and each limb.

Based on these hourly snapshot data, there was no clear evidence of I-IVLT having an effect on MEP amplitudes in lower limbs (MD 41.9, 95% CI −304.5 to 388.3; $p=.182$). In upper limbs, there was some evidence for a large difference favoring the use of intraoperative lidocaine (MD −279.0, 95% CI −562.5 to 4.4; $p=.054$) (Figure 2).

There was also no evidence of an effect of lidocaine on SSEP amplitudes between the two groups. Specifically, the linear mixed-effects model indicated no impact of I-IVLT on SSEP amplitudes in the lower limbs (MD 16.4, 95% CI [−17.7, 50.5]; $p=.345$) or in the upper limbs (MD −2.4, 95% CI [−14.5, 9.8]; $p=.701$) (Figure 3). Similarly, there was no evidence of a difference in SSEP latencies between groups in either lower limbs (MD 1.21, 95% CI [−1.29, 3.70]; $p=.343$) or upper limbs (MD 0.35, 95% CI [−1.82, 2.51]; $p=.754$) (Figure 3).

The amount of surgical time elapsed had an impact on the change from baseline of some IONPM measures, which was modified by the use of I-IVLT. There was an interaction between surgical time elapsed and I-IVLT use in upper limb MEP amplitude on change from baseline ($p=.047$). In those without lidocaine, increasing surgical time led to an average decrease of −31.31 (95% CI [−62.15, 0.49]) from baseline for each unit increase in time. In those with lidocaine infusion therapy, there was a positive association between time and a change from baseline of 8.82 (95% CI [−22.29, 39.91]), suggesting lidocaine may have a stabilizing effect on the MEP changes from baseline as the surgery progresses compared to no lidocaine. There was no evidence that surgical time elapsed had an effect on lower limb MEP amplitudes ($p=.980$) or lower limb SSEP amplitude ($p=.249$).

TABLE 2 Baseline neurophysiological monitoring and hourly intraoperative vital signs data.

	Study hour	Lidocaine group (N = 39)	n	No Lidocaine group (N = 42)	n
Baseline neurophysiological monitoring					
MEP amplitude (left AH)	Baseline	445 (200, 711)	39	582 (243, 922)	42
MEP amplitude (left TA)		389 (204, 797)		360 (143, 585)	
MEP amplitude (left APB)		414 (83982)		573 (154, 1333)	
MEP amplitude (left BR)		117 (51, 411)		237 (62, 421)	
MEP amplitude (right AH)		570 (187, 1209)		395 (183, 945)	
MEP amplitude (right TA)		358 (141, 678)		251 (113, 771)	
MEP amplitude (right APB)		632 (246, 1190)		696 (154, 1399)	
MEP amplitude (right BR)		181 (64, 337)		120 (73, 224)	
SSEP amplitude (post tib, Left)		2.4 (1.6, 3.5)		2.4 (1.5, 3.1)	
SSEP latency (post tib, left)		38.5 (36.4, 39.2)		38.1 (36.0, 40.1)	
SSEP amplitude (post tib, Right)		1.8 (1.3, 3.1)		2.0 (1.5, 3.1)	
SSEP Latency (post tib, Right)		37.5 (36.4, 39.2)		37.2 (36.2, 39.6)	
SSEP amplitude (ulnar, left)		1.2 (0.9, 2.0)		1.4 (1.1, 2.1)	
SSEP latency (ulnar, left)		20.3 (19.4, 21.7)		20.0 (19.4, 22.0)	
SSEP amplitude (ulnar, right)		1.5 (1.0, 1.9)		1.8 (1.2, 2.4)	
SSEP latency (ulnar, right)		20.6 (19.6, 21.7)		20.0 (19.2, 21.6)	
Hourly intraoperative vital signs data					
BIS monitoring	Baseline	32 (24.5, 39.5)	31	25.5 (21.0, 35.2)	38
	1	38.0 (30.0, 45.5)		32.5 (22.8, 42.5)	
	2	42.0 (32.0, 46.8)		34.0 (26.0, 40.5)	
	3	44.0 (41.5, 48.5)		42.5 (28.5, 50.3)	
	4	41.0 (36.3, 48.5)		46.0 (34.3, 54.8)	
	5	51.0 (42.0, 55.0)		47.0 (34.5, 56.0)	
MAP	Baseline	72.0 (59.0, 79.0)	39	62.5 (56.2, 73.8)	42
	1	70.0 (62.0, 73.0)		65.0 (60.0, 71.8)	
	2	67.0 (63.3, 73.8)		68.0 (61.3, 72.0)	
	3	68.5 (61.0, 78.3)		69.0 (60.3, 77.8)	
	4	68.0 (63.0, 72.5)		68.0 (63.0, 73.0)	
	5	69.0 (61.0, 76.5)		74.0 (63.0, 77.5)	
Body temperature	Baseline	36.2 (35.8, 36.4)	39	36.0 (35.7, 36.4)	42
	1	36.4 (35.9, 36.7)		36.4 (36.2, 36.7)	
	2	36.6 (36.4, 37.1)		36.6 (36.1, 36.8)	
	3	36.9 (36.7, 37.1)		36.7 (36.5,37.0)	
	4	36.7 (36.6, 37.1)		36.7 (36.5,36.9)	
	5	37.2 (37.0, 37.3)		36.7 (36.6, 37.1)	

Note: Data represented as median (interquartile range).

Abbreviations: AH, adductor hallucis; APB, adductor pollicis brevis; BIS, Bispectral Index; BR, brachoradialis; MAP, Mean Arterial Pressure; MEP, Motor Evoked Potential; post tib, posterior tibial; SSEP, Somatosensory Evoked Potential; TA, tibialis anterior.

There was also an interaction effect of I-IVLT and surgical time elapsed in upper SSEP amplitude ($p < .001$). In participants without I-IVLT, a small decrease of −3.13 (95% CI [−4.81, −1.46]) from baseline was associated with each unit increase in time. In those with I-IVLT, a similar decrease of −3.16 (95% CI [−4.85, −1.47]) was associated with increasing surgical time elapsed.

This interaction effect was mirrored in SSEP latency in both lower ($p < .001$) and upper ($p = .043$) limbs. In lower limbs, a slightly larger decrease from baseline of −0.907 (95% CI [−1.27, −0.556]) was associated with a one unit increase in time in those without lidocaine, while those with lidocaine had a smaller decrease of −0.653 (95% CI [−1.01, −0.30]) per increasing unit of time.

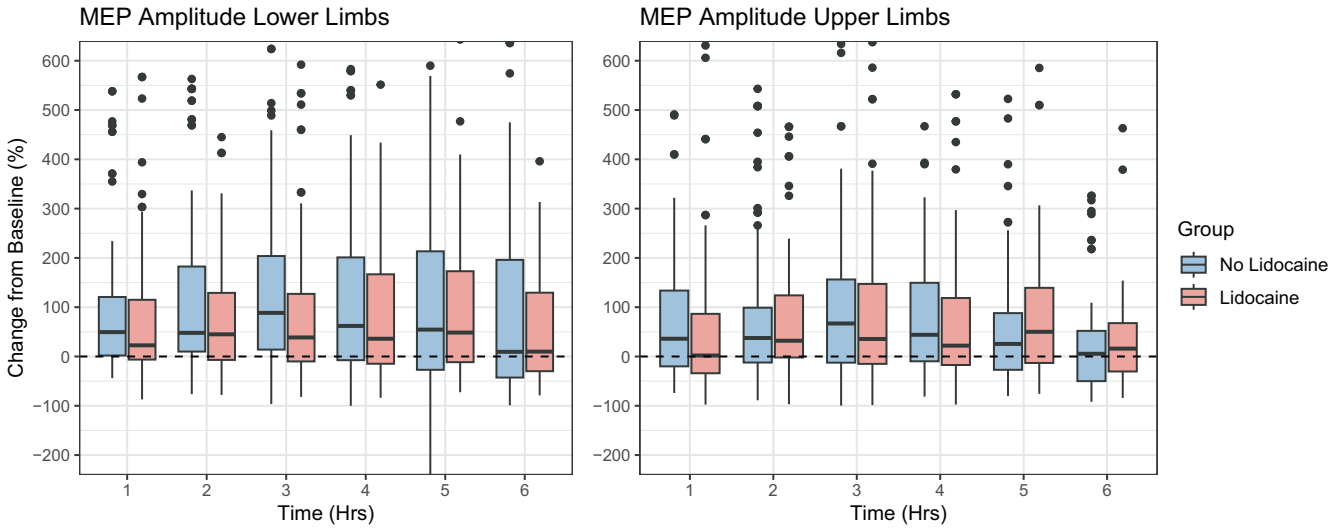

FIGURE 2 Box-and-Whisker plots representing the change in motor evoked potential (MEP) amplitude from baseline (%) in lower limbs (left sub-plot) and upper limbs (right sub-plot) over surgical time elapsed (hours) for No Lidocaine (blue) versus Lidocaine (red) cases. The center line denotes the median and boxes represent interquartile range with outliers denoted by black dots.

3.3 | Reportable neurophysiological events

One or more reportable IONPM events occurred in 43/81 (53%) participants. There was no difference between I-IVLT versus no lidocaine cases in the number of cases with reportable events (27 events occurred in 22/39 [56%] I-IVLT cases versus 32 events in 21/42 [50%] no lidocaine cases; RR = 0.87, 95% CI [0.55, 1.39], $p = .66$), or in the time to first reportable event (hazard ratio = 1.13, 95% CI [0.61, 2.09]; $p = .68$) (Figure 4). Median time to first event was 2.6 h (95% CI 2.2 to 4.0) for the I-IVLT group and 2.5 h (95% CI 1.4 to 4.7) for the no lidocaine group. For each event, one or more actions were taken, which included: repositioning of the arms ($n = 6$), adjusting anesthesia medication with the aim of increased MAP or reduced depth of anesthesia ($n = 27$), taking traction off ($n = 8$), increasing stimulation current ($n = 23$), using multiple stimulations ($n = 10$), and reversing surgical manipulation ($n = 4$); recovery was spontaneous in 13 cases. The numbers of times these actions were used were similar between I-IVLT and no lidocaine cases. Incomplete recovery of responses before end of surgery was noted in two I-IVLT cases and two no lidocaine cases.

3.4 | Exploratory noninferiority testing

The noninferiority of lidocaine was demonstrated in SSEP latency in both lower (MD 2.1, lower bound = 1.25; $p < .001$) and upper limbs (MD −0.86, lower bound = −1.58; $p < .001$) using a non-inferiority margin of −10. Non-inferiority was also demonstrated in SSEP amplitude in both lower (MD 9.77, 95% CI, lower bound = −3.98; $p < .001$) and upper limbs (MD −0.59, lower bound = −5.83; $p < .001$) using a non-inferiority margin of −50. In MEP data, noninferiority was demonstrated using the same margin in lower limbs (MD 130.6, lower bound =16.91; $p = .005$), but not in the upper limbs (MD 127.1, lower bound = −195; $p = .969$).

4 | DISCUSSION

In this single-centre, retrospective study, we observed a minimal impact of I-IVLT on IONPM during PSIF in adolescents with idiopathic scoliosis. We found no evidence of any detrimental impact of I-IVLT on MEP amplitude, SSEP amplitudes, or SSEP latencies, using samples of change from baseline in IONPM measurements collected at hourly intervals from upper and lower limbs. Similarly, we found no difference in the number of reportable neurophysiological events or in the time to first event.

The feasibility of I-IVLT during PSIF procedures requires that it has minimal impact on IONPM. The spine team depend on reliable IONPM during surgery to monitor the integrity of the spinal cord and make timely adjustments, if necessary. This contributes to improved patient safety and promotes successful outcomes. Lidocaine, administered intravenously, acts at multiple receptors, with analgesic, anti-inflammatory, and antihyperalgesic properties.[5,19] The analgesic properties are partly attributed to blockade of sodium channel nerve fibers and inhibition of the polysynaptic reflex induced by C-fibers and Aδ fibers.[20] Two clinical trials have found that intraoperative lidocaine infusion therapy has led to decreased hospital stay, decreased rescue analgesia requirements, decreased cortisol levels, and earlier return of bowel function following abdominal surgery[21] and spinal surgery;[7] similarly, reduced postoperative opioid requirements were reported in a retrospective observational study of adolescent patients undergoing scoliosis correction surgery.[6]

Our results extend the findings of an adult study of 129 spinal correction cases, which demonstrated that propofol-opioid TIVA with intraoperative lidocaine at a rate of 1.5 mg/kg/h had no effect on cortical SSEP or MEP amplitudes following median and posterior tibial nerve stimulation, nor any significant differences in MEP stimulation voltages.[22] A similar study in adults undergoing spinal correction surgery found no significant within-patient differences

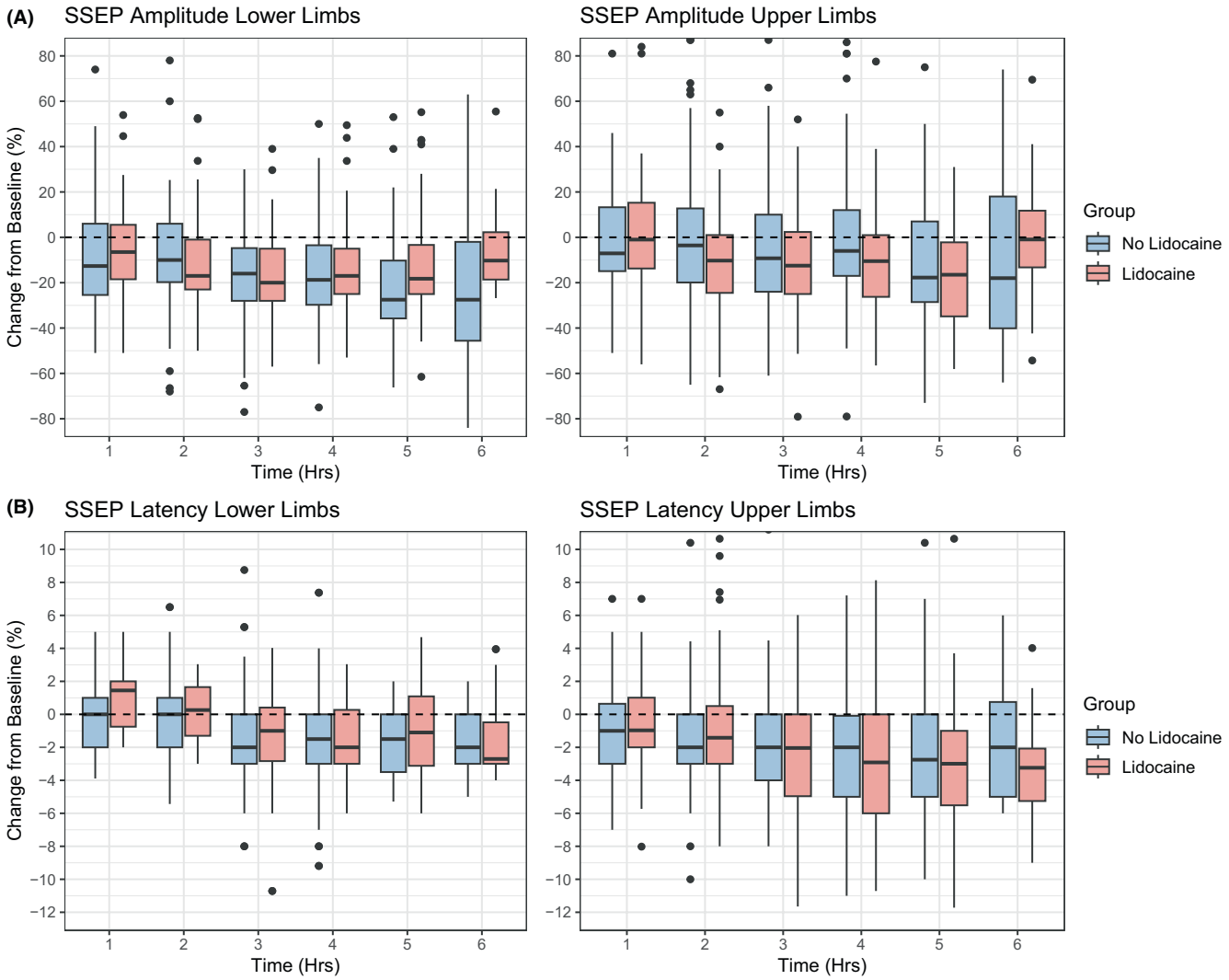

FIGURE 3 Box-and-Whisker plots representing the change in somatosensory evoked potential (SSEP) amplitude (A) and latency (B) from baseline (%) in lower limbs (left sub-plot) and upper limbs (right sub-plot) over surgical time elapsed (hours) for No Lidocaine (blue) and Lidocaine (red) cases. The center line denotes the median and boxes represent interquartile range with outliers denoted by black dots.

between MEP threshold voltages or SSEP amplitudes with intraoperative lidocaine infusion at a rate of 1.0 mg/kg/h following a 10-min bolus dose of 1.0 mg/kg.[23] Propofol-opioid TIVA was utilized in both studies; however, both analyses used threshold-voltage methodology and did not report on variability or alert criteria. Neuromonitoring methodology differences limit the possible comparison to our patient cohort.

A 40-patient randomized controlled trial investigating the effects of low-dose lidocaine (1 mg/kg bolus followed by 1 mg/kg/h infusion) in patients undergoing intracranial tumor resection with propofol-remifentanil anesthesia found no effect on MEP amplitude or latency, but did report improved hemodynamic stability, reduced propofol use, and decreased incidence of adverse events.[24] We similarly observed a negative interaction effect of the administration of lidocaine and surgical time elapsed in upper limb SSEP latency, suggesting that lidocaine administration may stabilize or reduces the negative impact of surgical time elapsed on the measured latency, which could indicate an improvement in IONPM measurement consistency. Further investigation is needed to establish robust evidence for this effect.

On the other hand, our findings contrast those of Chaves-Vischer et al. who found that a similar dosing regimen of 1 mg/kg lidocaine infusion decreased SSEP amplitude by 50% and increased latency by 5% in a case report of two adolescents undergoing scoliosis surgery.[13] The absence of precise dosing data in our analysis limits our ability to compare these results and both of Chaves-Vischer's patients received a nitrous oxide-fentanyl-midazolam regimen, which is not comparable with our TIVA approach. Our results also contrast those of Schubert et al., where intraoperative lidocaine infusion in 16 adolescents undergoing abdominal surgery resulted in a reduction in cortical SSEP amplitude by 25%–30% and a 5% increase in latency.[12] Again, comparison with our results is restricted by differences in lidocaine dosing and anesthetic approach: Schubert et al., employed a 3 mg/kg bolus of lidocaine followed by a 4 mg/kg/h. infusion, compared to our lower bolus dose of 1 mg/kg and 2 mg/kg/h. infusion. Schubert et al. used a sufentanil-nitrous oxide-isoflurane

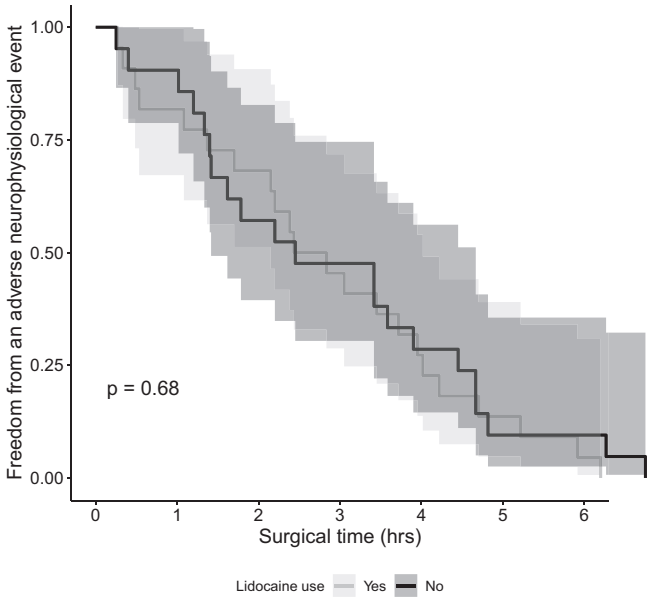

FIGURE 4 Kaplan–Meier curve of median time to first event (in surgical hours elapsed) for Lidocaine (gray) and No Lidocaine (black) cases, with *p*-value from the log-rank test. The shaded area represents the 95% confidence interval (CI) for the fitted curve.

anesthetic. Future prospective study is needed to address these discrepancies to determine dose response effects of lidocaine infusion therapy and its interaction with the chosen anesthetic regimen.

We also observed a significant negative effect of surgical time elapsed in both upper and lower limbs in MEP amplitude and SSEP amplitude and latency. This finding is consistent with previous studies indicating an increased likelihood of neurophysiological events with increasing surgical time elapsed during spinal corrective surgery.[25]

4.1 | Limitations

We had relatively small numbers in each group for the power to detect differences, which is reflected in some of our wide CIs. While we found no evidence that I-IVLT had any detrimental effect on IONPM outcomes, we must be cautious in generalizing these findings from this sample. Matching on patient risk factors such as sex, age, Cobb angle, procedure details, surgical duration (±1 h), and surgeon may have improved this precision but was not feasible in our sample. Prospective study is required to establish the validity and reliability of our finding.

Clinical neurophysiological parameters' recording standards have evolved over time, leading to variability among technologists in the content of the IONPM files we analyzed. Some potentially impactful data points were recorded inconsistently across cases. Therefore, future investigations should incorporate a standardized variable proforma for comprehensive data collection.

Our study did not have a standardized anesthetic regime as this was a retrospective study. Presently, our institution employs a TIVA approach, typically comprising propofol and sufentanil, with or without adjunctive agents including ketamine or lidocaine. We did not collect specific drug doses or exact timing of administration in this retrospective study; these details should be available in a future prospective study. However, for the cases in which I-IVLT was used, we know that it was maintained at standardized doses (1 mg/kg bolus followed by 2 mg/kg/h until end of surgery). This dose regime has previously been shown to achieve clinically effective and safe blood levels (<3 μg/mL) in healthy patients.[26]

It is important to note that many of our statistical analyses had wide CIs, illustrating a high degree of uncertainty in our data. While we can draw tentative conclusions about the safety of I-IVLT, this motivates the need for a more robust, prospective trial.

4.2 | Conclusion

Our findings suggest that intraoperative intravenous lidocaine infusion therapy has no detrimental effect on IONPM in adolescents undergoing PSIF for adolescent idiopathic scoliosis. A future prospective randomized study is required to provide a more detailed and reliable analysis by controlling for the limitations outlined in this analysis.

FUNDING INFORMATION

Funded in part by a BC Children's Hospital Research Institute summer studentship (B Hoffmann) and BioTalent Canada (R Bates).

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The author elects to not share data.

ETHICS STATEMENT

The study was approved by the UBC Children's and Women's Health Centre of BC Research Ethics Board (H20-01875).

ORCID

Nicholas West https://orcid.org/0000-0001-8382-5136

REFERENCES

1. Chidambaran V, Ding L, Moore DL, et al. Predicting the pain continuum after adolescent idiopathic scoliosis surgery: a prospective cohort study. *Eur J Pain*. 2017;21(7):1252-1265.
2. Lee CS, Merchant S, Chidambaran V. Postoperative pain management in pediatric spinal fusion surgery for idiopathic scoliosis. *Paediatr Drugs*. 2020;22(6):575-601.
3. Patel J, Snyder K, Brooks AK. Perioperative pain optimization in the age of the opioid epidemic. *Curr Opin Anaesthesiol*. 2024;37(3):279-284.
4. Shah SA, Guidry R, Kumar A, White T, King A, Heffernan MJ. Current trends in pediatric spine deformity surgery: multimodal pain management and rapid recovery. *Glob Spine J*. 2020;10(3):346-352.
5. Lauder GR. A review of intravenous lidocaine infusion therapy for Paediatric acute and chronic pain management. In: Maldonado

C, ed. *Pain Relief—From Analgesics to Alternative Therapies*. InTech; 2017. Accessed March 20, 2024. 10.5772/66771.
6. Lin R, Zhu K, Poznikoff AK, Görges M, Brown ZE. The effect of intraoperative lidocaine infusion on postoperative opioid consumption in adolescents undergoing posterior spinal instrumentation and fusion for idiopathic scoliosis. *Spine J*. 2021;21(7):1047-1048.
7. Kim K-T, Cho D-C, Sung J-K, et al. Intraoperative systemic infusion of lidocaine reduces postoperative pain after lumbar surgery: a double-blinded, randomized, placebo-controlled clinical trial. *Spine J*. 2014;14(8):1559-1566.
8. Kranke P, Jokinen J, Pace NL, et al. Continuous intravenous perioperative lidocaine infusion for postoperative pain and recovery. *Cochrane Database Syst Rev*. 2015;7:CD009642.
9. Halsey MF, Myung KS, Ghag A, Vitale MG, Newton PO, de Kleuver M. Neurophysiological monitoring of spinal cord function during spinal deformity surgery: 2020 SRS neuromonitoring information statement. *Spine Deform*. 2020;8(4):591-596.
10. Velayutham P, Cherian VT, Rajshekhar V, Babu KS. The effects of propofol and isoflurane on intraoperative motor evoked potentials during spinal cord tumour removal surgery—a prospective randomised trial. *Indian J Anaesth*. 2019;63(2):92-99.
11. Sloan T. Anesthesia and intraoperative neurophysiological monitoring in children. *Childs Nerv Syst*. 2010;26(2):227-235.
12. Schubert A, Licina MG, Glaze GM, Paranandi L. Systemic lidocaine and human somatosensory-evoked potentials during sufentanil-isoflurane anaesthesia. *Can J Anaesth*. 1992;39(6):569-575.
13. Chaves-Vischer V, Brustowicz R, Helmers SL. The effect of intravenous lidocaine on intraoperative somatosensory evoked potentials during scoliosis surgery. *Anesth Analg*. 1996;83(5):1122-1125.
14. von Elm E, Altman DG, Egger M, et al. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ*. 2007;335(7624):806-808.
15. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377-381.
16. Hernández-Palazón J, Izura V, Fuentes-García D, Piqueras-Pérez C, Doménech-Asensi P, Falcón-Araña L. Comparison of the effects of Propofol and Sevoflurane combined with remifentanil on transcranial electric motor-evoked and somatosensory-evoked potential monitoring during brainstem surgery. *J Neurosurg Anesthesiol*. 2015;27(4):282-288.
17. Yue H, Zhou M, Chong Y, et al. Effects of lidocaine on motor-evoked potentials and somatosensory-evoked potentials in patients undergoing intraspinal tumour resection: study protocol for a prospective randomized controlled trial. *J Pain Res*. 2022;15:287-297.
18. The R Foundation. The R Project for Statistical Computing [Internet]. 2024. [Accessed March 20, 2024]. https://www.r-project.org/
19. Kim Y-C, Castañeda AM, Lee C-S, Jin H-S, Park KS, Moon JY. Efficacy and safety of lidocaine infusion treatment for neuropathic pain: a randomized, double-blind, and placebo-controlled study. *Reg Anesth Pain Med*. 2018;43(4):415-424.
20. Wang Q, Ding X, Huai D, Zhao W, Wang J, Xie C. Effect of intravenous lidocaine infusion on postoperative early recovery quality in upper airway surgery. *Laryngoscope*. 2021;131(1):E63-E69.
21. El-Deeb A, El-Morsy GZ, Ghanem AAA, Elsharkawy AA, Elmetwally AS. The effects of intravenous lidocaine infusion on hospital stay after major abdominal pediatric surgery. A randomized double-blinded study. *Egypt J Anaesth*. 2013;29(3):225-230.
22. Sloan TB, Mongan P, Lyda C, Koht A. Lidocaine infusion adjunct to total intravenous anesthesia reduces the total dose of propofol during intraoperative neurophysiological monitoring. *J Clin Monit Comput*. 2014;28(2):139-147.
23. Urban MK, Fields K, Donegan SW, et al. A randomized crossover study of the effects of lidocaine on motor- and sensory-evoked potentials during spinal surgery. *Spine J*. 2017;17(12):1889-1896.
24. Liu M, Wang N, Wang D, Liu J, Zhou X, Jin W. Effect of low-dose lidocaine on MEPs in patients undergoing intracranial tumor resection with propofol anesthesia: a randomized controlled trial. *Medicine (Baltimore)*. 2022;101(32):e29965.
25. Ugawa R, Takigawa T, Shimomiya H, et al. An evaluation of anesthetic fade in motor evoked potential monitoring in spinal deformity surgeries. *J Orthop Surg Res*. 2018;13(1):227.
26. Altermatt FR, Bugedo DA, Delfino AE, et al. Evaluation of the effect of intravenous lidocaine on propofol requirements during total intravenous anaesthesia as measured by bispectral index. *Br J Anaesth*. 2012;108(6):979-983.
27. Park J-H, Hyun S-J. Intraoperative neurophysiological monitoring in spinal surgery. *World J Clin Cases*. 2015;3(9):765-773.
28. de Klerk CCJM, Johnson MH, Southgate V. An EEG study on the somatotopic organisation of sensorimotor cortex activation during action execution and observation in infancy. *Dev Cogn Neurosci*. 2015;15:1-10.
29. MacDonald DB. Safety of intraoperative transcranial electrical stimulation motor evoked potential monitoring. *J Clin Neurophysiol*. 2002;19(5):416-429.

How to cite this article: Bates R, Cave F, West N, et al. Intravenous lidocaine infusion therapy and intraoperative neurophysiological monitoring in adolescents undergoing idiopathic scoliosis correction: A retrospective study. *Pediatr Anesth*. 2025;35:47-56. doi:10.1111/pan.15019

APPENDIX A

Intraoperative neurophysiological monitoring during posterior spinal instrumentation and fusion surgery at BC Children's Hospital

The somatosensory evoked potentials (SSEPs) and motor evoked potentials (MEPs) of the upper and lower limbs were monitored with the Cadwell Cascade PRO (2012–2019) or Cascade IOMAX (2019–2021) neurophysiological monitoring system (Cadwell Laboratories Inc, WA).

Following anesthesia induction, monitoring and stimulation electrodes were placed on the scalp in accordance with the international 10–20 system[27,28] using subcutaneous corkscrew electrodes. Subcutaneous needle electrodes were used to monitor the muscle potentials placed bilaterally in the adductor hallucis (AH), tibialis anterior (TA), brachioradialis (BR), and adductor pollicis brevis (APB), with stimulation electrodes in the M1-M2, M3 and M4 positions. Stimulation was delivered by constant current electrical stimulator using multiple pulses (1–6) with voltage starting at 150 V and gradually increasing at 50V intervals as needed with a pulse duration of 50–75 μs, ranging from 150 to 800 V.

Conductive gel electrodes, used to stimulate the SSEP responses for the upper limbs, were placed on both wrists to stimulate the ulnar nerves. Responses were recorded from electrodes C3′, C4′ (2 cm behind C3 and C4 respectively) and a reference electrode placed at FZ. Stimulation electrodes for the lower limbs were placed on both ankles to stimulate the posterior tibial nerve, with responses recorded

usually from Cz′. The derivations deemed the most stable was chosen for monitoring the case.[29] The stimulation for the SSEP used a frequency of 2.1-4.7 Hz, with an intensity between 20 and 50 mA.

During the operative procedure, reliable data for the measurement of spinal cord function was recorded in the form of amplitudes and latencies of the SSEP and MEP. Initial recordings were taken once the patient was on stable intravenous anesthesia. Stimulus intensities were altered in relation to the alert criteria set as a 50% drop in amplitude of the MEP and a 50% drop in amplitude or a 10% increase in latency in two or more derivations of the SSEP. There was no exceeding the following stimulation: >50 mA for the SSEP and 800 single train and 500 V double train stimulation.