BMJ Paediatrics Open

Postoperative pain and pain management following selective dorsal rhizotomy

Isabel G Adams ,[1] Ramanie Jayaweera,[2] Jennifer Lewis,[2] Nadia Badawi,[3,4] Mohamed E Abdel-Latif ,[1,5] Simon Paget[2,6]

To cite: Adams IG, Jayaweera R, Lewis J, *et al*. Postoperative pain and pain management following selective dorsal rhizotomy. *BMJ Paediatrics Open* 2024;**8**:e002381. doi:10.1136/bmjpo-2023-002381

Received 9 November 2023
Accepted 4 March 2024

[1]Australian National University College of Health and Medicine, Canberra, Australian Capital Territory, Australia
[2]The Children's Hospital at Westmead, Westmead, New South Wales, Australia
[3]Discipline of Child and Adolescent Health, University of Sydney, Cerebral Palsy Alliance, Sydney, New South Wales, Australia
[4]Grace Centre for Newborn Care, The Children's Hospital at Westmead, Westmead, New South Wales, Australia
[5]Neonatology, Canberra Hospital, Canberra, Australian Capital Territory, Australia
[6]Faculty of Medicine and Health, The University of Sydney Children's Hospital Westmead Clinical School, Westmead, New South Wales, Australia

Correspondence to
Dr Simon Paget; simon.paget@sydney.edu.au

ABSTRACT

Background Selective dorsal rhizotomy (SDR) is a neurosurgical procedure that reduces lower limb spasticity, performed in some children with spastic diplegic cerebral palsy. Effective pain management after SDR is essential for early rehabilitation. This study aimed to describe the anaesthetic and early pain management, pain and adverse events in children following SDR.

Methods This was a retrospective cohort study. Participants were all children who underwent SDR at a single Australian tertiary hospital between 2010 and 2020. Electronic medical records of all children identified were reviewed. Data collected included demographic and clinical data (pain scores, key clinical outcomes, adverse events and side effects) and medications used during anaesthesia and postoperative recovery.

Results 22 children (n=8, 36% female) had SDR. The mean (SD) age at surgery was 6 years and 6 months (1 year and 4 months). Common intraoperative medications used were remifentanil (100%), ketamine (95%), paracetamol (91%) and sevoflurane (86%). Postoperatively, all children were prescribed opioid nurse-controlled analgesia (morphine, 36%; fentanyl, 36%; and oxycodone, 18%) and concomitant ketamine infusion. Opioid doses were maximal on the day after surgery. The mean (SD) daily average pain score (Wong-Baker FACES scale) on the day after surgery was 1.4 (0.9), decreasing to 1.0 (0.5) on postoperative day 6 (POD6). Children first attended the physiotherapy gym on median day 7 (POD8, range 7–8). Most children experienced mild side effects or adverse events that were managed conservatively. Common side effects included constipation (n=19), nausea and vomiting (n=18), and pruritus (n=14). No patient required return to theatre, ICU admission or prolonged inpatient stay.

Conclusions Most children achieve good pain management following SDR with opioid and ketamine infusions. Adverse events, while common, are typically mild and managed with medication or therapy. This information can be used as a baseline to improve postoperative care and to support families' understanding of SDR before surgery.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Pain management following selective dorsal rhizotomy (SDR) is essential for functional recovery, but research is still emerging and lacks consistency in pain reporting. Multimodal analgesia is a popular regime for postoperative pain management, often based on continuous opioid infusions.

WHAT THIS STUDY ADDS

⇒ Pain at our tertiary centre is well controlled with multimodal analgesia consisting of a continuous opioid and ketamine infusion. Neither pain nor adverse events limited participation in physiotherapy from the intended start date.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study provides evidence to inform a local best-practice approach to pain management in cerebral palsy (CP) following SDR, with effective inclusion of pain scores and pain reporting systems. This study also provides insight for families and clinicians into the postoperative course of children with CP undergoing this surgery.

INTRODUCTION

Cerebral palsy (CP) is the most common physical disability affecting children. In Australia, CP occurs in 1.4 of 1000 live births, although this incidence is declining.[1] CP is broadly recognised as a 'group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing foetal or infant brain'.[2] CP can be classified into four major categories: spastic, dyskinetic, ataxic and hypotonic.[1] Of these, spastic CP is the most common, affecting 80% of children with CP.[3]

Spasticity is a major cause of disability in children with CP, contributing to pain and muscle and joint deformity.[4] As such, treatment of spasticity has become a central feature of management for children with CP. Selective dorsal rhizotomy (SDR) is a neurosurgical procedure aimed at permanently reducing lower limb spasticity in children with CP by selectively targeting and removing sensory rootlets with aberrant activity.[4 5] There has

been substantial research examining outcomes related to SDR in recent years.[4–10] Most studies report durable improvements in spasticity and gait, with physiotherapy post-SDR playing a large role in these gains.[4 5 9 10] Gross motor function and mobility tend to improve in the short term, as do patient care and mood.[4 6 9 11]

Children undergoing SDR often experience significant pain and discomfort in the immediate postoperative period.[12 13] This is thought to be the combined effect of the surgery itself, irritation of nerve roots and muscle spasm.[12–14] Postoperative pain is often distressing for patients and their families and can result in complications, delayed participation in therapy and poor functional recovery.[14 15] As such, effective pain management is essential to ensure optimal recovery post-SDR.

While research into postoperative pain management in children following SDR is emerging, there is limited evidence to inform a best-practice approach. A recent systematic review found reasonable evidence for the use of intrathecal or epidural morphine for pain management post-SDR.[16] Another study similarly suggests that continuous opioid infusions are the regimen of choice for most centres performing SDR worldwide.[13] More recently, Hatef *et al* describe the use of a multimodal epidural regime as an alternative to continuous intravenous opioid infusions in children with CP post-SDR.[12] Multimodal analgesia, or the synergistic combination of multiple analgesic agents at lower doses, has the potential to reduce postoperative pain, opioid use, the incidence of adverse events associated with higher dosing and the length of hospital stay following major orthopaedic or spine surgery.[15 17 18] Another confounding factor in existing literature is the lack of consistency in reporting pain scores, with several studies not recording pain scores in the first place.[13 16] The variety of approaches and the lack of any local consensus highlight the need to inform a best-practice pain management approach following SDR with a particular focus on improving the inclusion of pain scores and standardised pain reporting systems.

The aim of this research was to describe the anaesthetic and early analgesic management of pain in children with CP following SDR to support a best-practice approach to improved pain management and functional recovery. This includes an assessment of pain, side effects and adverse events of pain management in the postoperative period.

METHODS

Study design

This study was a retrospective cohort study.

Population

The population included children with CP who had SDR surgery at The Children's Hospital at Westmead between 2010 and 2020, identified from the Australian SDR Registry.[7] There was no patient or public involvement in the design of this study.

Surgical technique

All patients underwent a multilevel laminoplasty. The cauda equina was exposed from the vertebral levels L2 to S1 via laminoplasty. Dorsal roots were distinguished from motor roots on each side at each level and divided into rootlets. Electrophysiology enabled the identification of individual dorsal rootlets that responded more strongly to corresponding muscle stimulation, and these rootlets were cut (approximately 30% transected at each level).

Data collection

Electronic medical records of patients were reviewed. Patient demographics were collected, including date of birth, gender and weight. The date of surgery, time of anaesthetic induction and time of recovery initiation were recorded. From anaesthetic records, the major operative anaesthetic agents were recorded.

Postoperative pain and pain management

Following surgery, patients were transferred from recovery to a general paediatric surgical ward and were not required to stay in a high-dependency unit or equivalent service. Pain management included nurse-controlled analgesia (NCA) infusion (opioid analgesia) which was managed on the ward and reviewed daily by an Acute Pain Service team. Children under 12 years old had a background infusion programmed into their NCA in addition to a bolus function. Determination to wean NCA was multifactorial, guided by a global assessment of all analgesic methods, pain scores and whether the patient could tolerate oral intake. In general, patients were weaned from NCA if they required infrequent boluses, reported pain scores below 3 on the Wong-Baker FACES scale and could tolerate oral analgesia.

Postoperatively, data for opioid, ketamine and non-opioid medication usage were recorded. The doses of opioid medications were converted to morphine milligram equivalents (MMEs) to allow comparison between patients using different opioids. Starting from the day of surgery (postoperative day 1, POD1), hourly pain scores were recorded by the nursing team using the Wong-Baker FACES scale. The mean, minimum and maximum pain scores for each POD were recorded up to a maximum of POD6, by which point the NCA infusion had been weaned off in all patients.

Postoperative milestones

Postoperative milestones included the first day the patient attended the physiotherapy gym, the first day sitting in bed (with the bedhead raised to 30°) and the date of removal of the patient's indwelling urinary catheter (IDC) and nasogastric tube (NGT).

Adverse events and side effects

Adverse events collected included desaturation requiring oxygen and oversedation requiring a reduction of dosage. Side effects of nausea and vomiting, constipation, urinary retention and pruritus were also collected.

Table 1 Patient demographics

Age at surgery (mean±SD)	6 years and 6 months±1 year and 4 months
Weight (kg) (mean±SD)	20.5±4.7
Female (n, %)	8, 36%
GMFCS level II (n, %)	8, 36%
GMFCS level III (n, %)	14, 64%
Surgery in 2010–2015 (n, %)	10, 45%
Surgery in 2016–2020 (n, %)	12, 55%

Total number of patients = 22.
GMFCS, Gross Motor Function Classification System; SD, Standard Deviation.

Statistical analysis

Data for anaesthetic administration were divided into 5-year periods to assess for any variation in protocol or any changes in common medications over time. Pain scores were treated as a continuous variable, and any analyses on pain scores were assigned one decimal place. Total doses of medications administered on the day of surgery (POD1) were adjusted to account for the reduced number of hours and enable comparison of this and subsequent PODs.

Due to the small number of patients in the study, comparative statistical analyses were not performed. Preliminary t-tests revealed no significant difference in any circumstance, which was expected given our sample sizes. Instead, we have described meaningful trends observed in the data.

RESULTS

22 patients (n=8, 36% female) were identified as having had SDR surgery from 2010 to 2020 (table 1). All patients had a diagnosis of bilateral spastic CP.

Anaesthetic management

The use of anaesthetic medications during SDR surgery can be seen in figure 1.

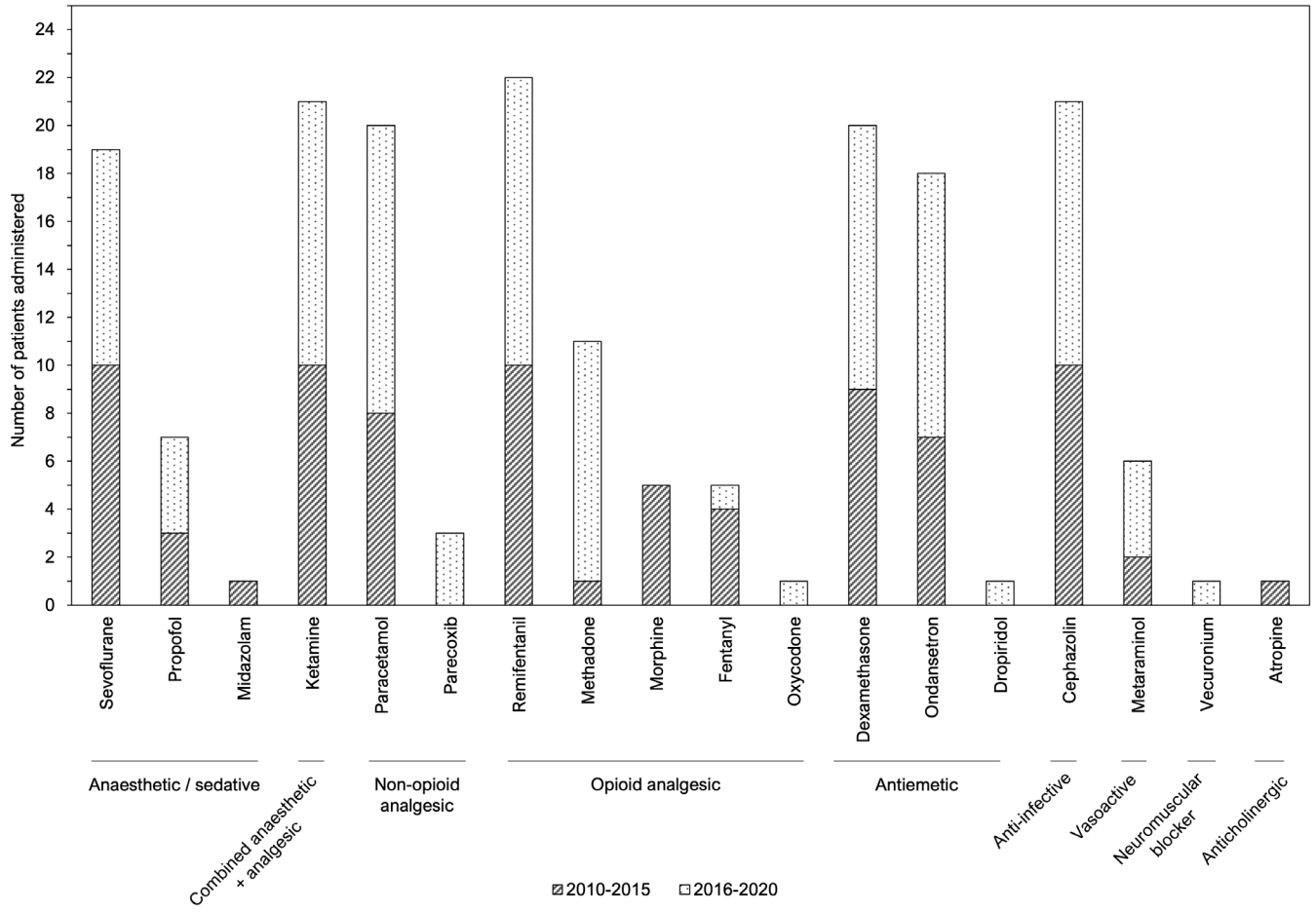

Figure 1 Intraoperative medications used in selective dorsal rhizotomy per 5-year period. All patients (n=22, 100%) underwent multilevel laminoplasty at a single Australian tertiary hospital. Patients were stratified based on the 5-year period in which their surgery took place (2010–2015, n=10, 45%; 2016–2020, n=12, 55%). Intraoperative medications were classified based on the category of use, and values represent the number of patients administered each medication.

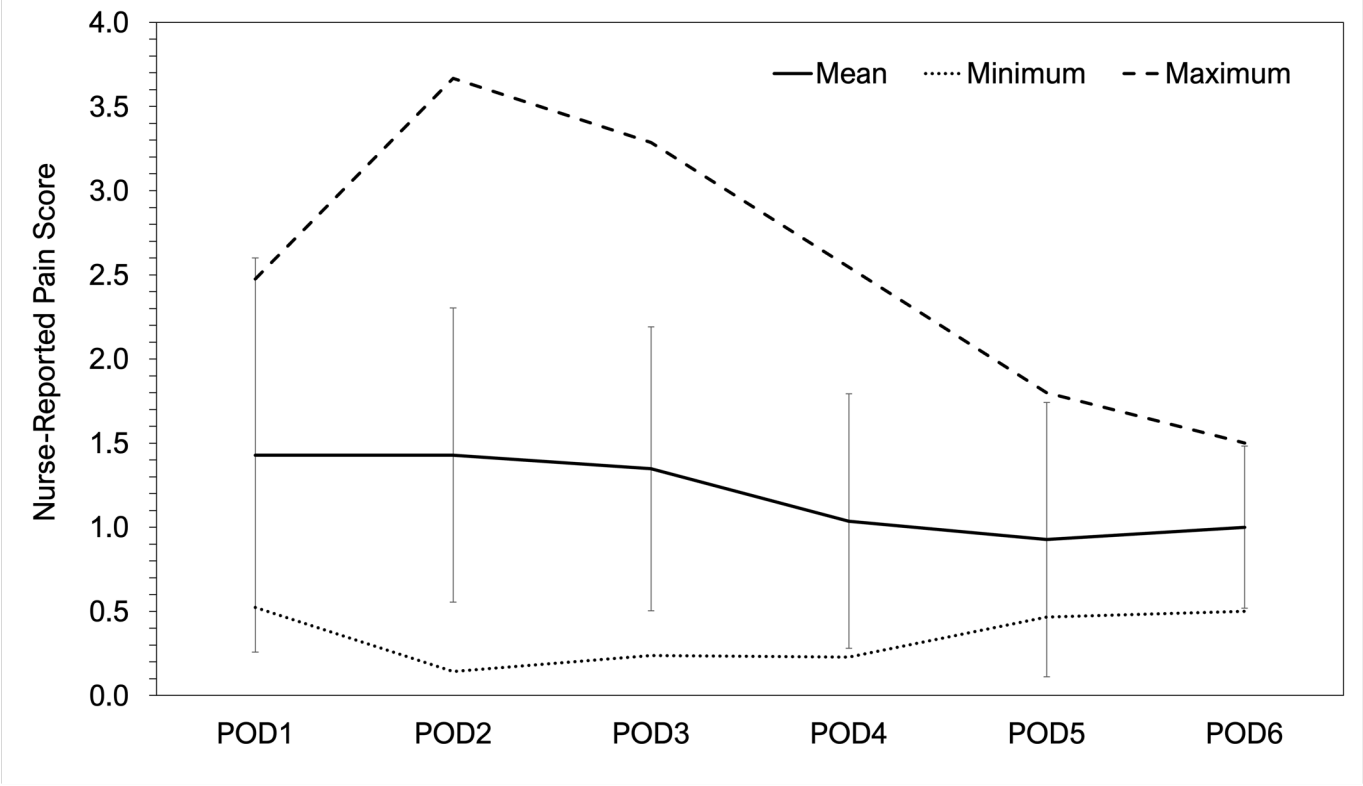

Figure 2 Daily average postoperative pain experienced by children following selective dorsal rhizotomy. Pain scores for all patients (n=22, 100%) were recorded hourly by nurses according to the Wong-Baker FACES scale. Averaged mean, minimum and maximum reported scores for each postoperative day (POD) are present. POD1 is given as the day of surgery. Standard deviation has been included for the mean scores (error bars).

All patients (n=22, 100%) were administered remifentanil during surgery, an opioid anaesthetic and analgesic. Other opioid analgesics used during the operative period included methadone (n=11, 50%), morphine (n=5, 23%), fentanyl (n=5, 23%) and oxycodone (n=1, 5%). Almost all patients received ketamine (n=21, 95%), cephazolin (n=21, 95%), paracetamol (n=20, 91%), dexamethasone (n=20, 91%) and sevoflurane (n=19, 86%). There was only minor variation in medications used between the 2010–2015 period and the 2016–2020 period. Parecoxib, methadone and oxycodone were only recently introduced to the anaesthetic protocol and were therefore used almost exclusively in the 2016–2020 period.

Postoperative pain and pain management

Daily average postoperative pain scores can be seen in figure 2.

The mean daily average pain score was maintained at a low score and appeared to decrease between POD1 and POD6. Both the maximum and minimum daily average pain scores peaked on POD2. A smaller range of pain scores was recorded on POD6. Children typically described leg and/or back pain, particularly on movement and repositioning.

Opioid analgesia usage in the postoperative period is shown in figure 3.

22 (100%) patients received opioid analgesia via NCA intravenous infusion. Opioids prescribed were morphine (n=8, 36%), fentanyl (n=8, 36%) or oxycodone (n=4, 18%). 20 patients (9%) started on morphine and transitioned to fentanyl due to significant nausea. Opioid use continued until the latest of POD6. There was a wide range of total opioid use on POD1 with one patient (5%) not receiving any opioid analgesia on this day. The highest median total opioid dose occurred on POD2, with the median dose decreasing each subsequent POD. The maximum total opioid dose also appeared to decrease from POD1, with a maximum total dose of 0.2 MME/kg per day on POD6.

In addition to regular opioid administration, ketamine was administered to all patients (n=22, 100%) at a mean dose of 5.0 µg/kg per hour (SD 0.3). Four patients (18%) had a combined infusion of ketamine and opioid analgesia, so data for the mean daily amount of ketamine were not present. The mean daily amount of ketamine on the day of surgery (POD1) was 596.4 µg/kg per day (SD 318.7). This increased to 762.0 µg/kg per day (SD 487.6) on the day after surgery (POD2) and then decreased to 97.4 µg/kg per day (SD 192.0) on POD5. Ketamine was administered for a mean duration of 4 days (POD4). The maximum duration of ketamine infusion was until POD6, and the minimum duration was until POD2.

Standard medications of interest included gabapentinoids (gabapentin and pregabalin), amitriptyline, diazepam, oxycodone, paracetamol and ibuprofen (table 2).

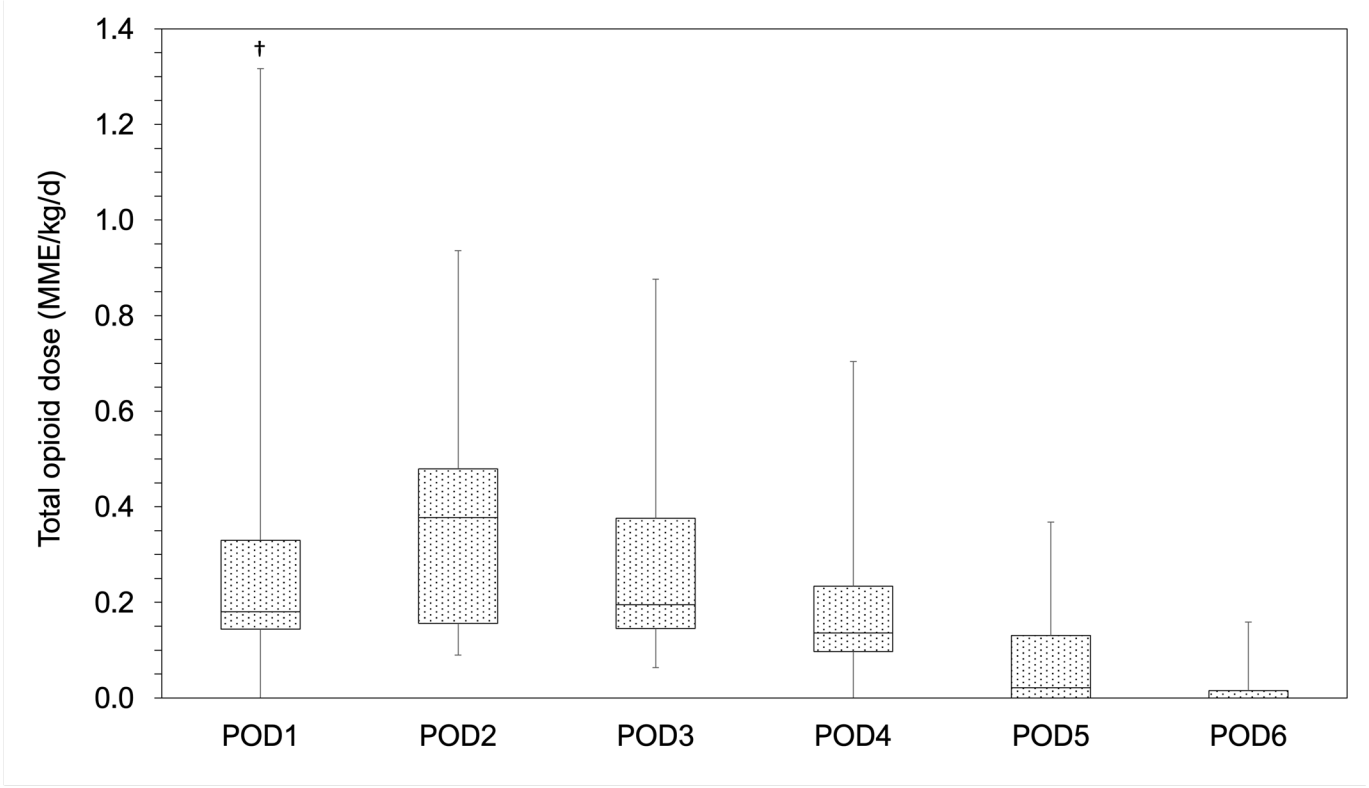

Figure 3 Postoperative opioid analgesia usage following selective dorsal rhizotomy. Patients (n=22, 100%) were administered morphine (n=8, 36%), fentanyl (n=8, 36%) or oxycodone (n=4, 18%) via nurse-controlled analgesia intravenous infusions. Total daily doses of opioids were converted to morphine milligram equivalents to allow for comparison between different opioids. Data for each postoperative day (POD) are shown as a box-and-whisker plot, with quartile 1, median and quartile 3; the whiskers represent the range. POD1 is given as the day of surgery. † POD1 was given threefold weighting.

The most commonly prescribed medications were paracetamol (n=22, 100%), diazepam (n=21, 95%) and oxycodone (n=20, 91%). The most common gabapentinoid was gabapentin (n=13, 59%).

Postoperative milestones

Removal of patients' NGT and IDC similarly occurred after a median of 4 days (POD5, range 1–10 days and 3–8 days, respectively) postoperatively. Patients sat at 30° elevation in bed for the first time after a median of 4 days (POD5, range 2–4 days) postoperatively. The first day in the physiotherapy gym occurred after a median of 7 days (POD8, range 7–8 days) postoperatively.

Table 2 Standard postoperative medications

Medication	Dose (µg/kg/d) (mean±SD)	Number of patients used (n, %)
Gabapentin	23.5±5.9	13, 59%
Pregabalin	4.8±2.3	9, 41%
Amitriptyline	0.3	1, 5%
Diazepam	0.2±0.1	21, 95%
Oxycodone	0.2±0.1	20, 91%
Paracetamol	36.8±5.8	22, 100%
Ibuprofen	14.6±5.3	8, 36%

Total number of patients = 22.
SD, Standard Deviation.

Adverse events and side effects

No serious adverse events occurred throughout the postoperative period that required return to theatre, intensive care admission or prolonged inpatient stay. Many patients experienced mild side effects or adverse events, the most common being constipation (n=19, 86%), nausea and vomiting (n=18, 82%), pruritus (n=14, 64%) and desaturation (n=12, 55%). Patients less frequently experienced oversedation (n=4, 18%) or urinary retention (n=2, 9%). All side effects were conservatively managed, either by monitoring, therapy (eg, massage for pruritus) or medication. Most patients experienced recurrent episodes of desaturation, requiring supplemental oxygen on all occasions. Oversedation tended to occur only once in patients and was managed via adjusting medication or dose.

DISCUSSION

This study is one of the few to describe postoperative pain and pain management in children with CP following SDR surgery. Postoperative pain peaked on the day after surgery (POD2), before steadily decreasing to POD6.

Postoperative pain management involved a multimodal approach of continuous opioid infusions in all patients and concomitant ketamine infusions. Both the median total opioid dose and mean ketamine dose peaked on POD2, consistent with peak pain scores.

Functional gains after SDR are dependent on early and intensive rehabilitation, which may be significantly impeded by postoperative pain or complications. Pain following SDR may derive from multiple causes, including the laminoplasty itself, dysaesthesia or hyperaesthesia from manipulation of nerve roots and lower limb muscle spasms.[12–14 19] Pain pathophysiology in CP may be more complex and heterogeneous than previously acknowledged and is likely to be heightened following invasive procedures, making pain management in this population challenging.[20] Our results support that pain is generally well managed, including avoidance of serious adverse events, in children following SDR at this centre using a multimodal approach enabling early commencement of postoperative rehabilitation. Common adverse events and side effects included constipation and nausea and vomiting, although none were severe enough to necessitate intensified care or delayed participation in therapy. The benefits of early therapy are clear, with the combination of physical therapy and SDR shown to almost double the short-term improvements to spasticity and gross motor function than from therapy alone.[10] The physiotherapy regimen for our patient population is scheduled to start early in the postoperative course, commencing with gentle bed exercises 2–3 days post-SDR and transitioning to gym-based therapy at 7 days postoperatively (POD8). While the start date for physiotherapy in the gym is based on patient comfort (tending to occur following IDC removal) and transfer ability, it is largely reliable, occurring at a maximum of 8 days postoperatively.

The postoperative pain management we describe here is like that described in literature. Continuous opioid infusions are common practice for post-SDR pain management worldwide, with reports of using intravenous,[13 19] intrathecal[16] or epidural[13 14 16] morphine or intravenous or epidural fentanyl[13] (we found no studies citing the use of continuous oxycodone). More recently, a wave of non-opioid pain management protocols have emerged that describe fewer side effects (eg, pruritus, nausea and vomiting) and either no difference in pain scores[12 21] or a trend towards less severe pain[14] compared with continuous opioid infusions.

Pain following SDR surgery has been shown to peak within the first few days following surgery,[19] yet very few studies provide a quantification of pain scores in the post-SDR period. The studies that do quantify pain use scoring systems such as the Wong-Baker FACES scale[21] or the face-legs-activity-cry-consolability (FLACC) scale[12 14] and/or a numerical rating scale of various magnitude,[21] where the choice of scoring system usually depends on patient age.[16] Using a numerical or Wong-Baker FACES scale, Pao *et al* recorded average pain scores of 2.6–3.0 out of 10 on the day of surgery, decreasing to 0.5–0.6 on the third POD, with lower pain scores perhaps attributable to their single-level approach.[21] Greater cumulative scores were recorded by Hatef *et al* using a FLACC pain scale, where average pain throughout the postoperative period was around 1.0 out of 10 and maximum pain closer to 5.0.[12]

Strengths of this study include the inclusion of postoperative pain scores following SDR surgery and the use of patient registry data that enable us to be confident that no cases were missed. While this research provides meaningful information regarding postoperative pain and pain management, the protocol presented here is based on institutional and cultural preference. In a similar vein, our protocol is based on a multilevel laminoplasty approach, and there may be different pain profiles and adverse events associated with other surgical techniques. However, a recent study compared the outcomes of SDR at the conus medullaris (single-level) with that at the cauda equina (multilevel) and found no significant meaningful difference between the two techniques in terms of postoperative path and adverse events.[22] While the aforementioned authors did not specifically look at pain scores, they remark that both groups participated in therapy from their scheduled start, suggesting little difference in interference by pain.

This study is the first in Australia to our knowledge to quantify pain and outline an effective pain management strategy post-SDR. Most children achieve good pain management following SDR surgery using a multimodal analgesia regimen of opioids and ketamine, like other protocols described in literature. While side effects and adverse events were common, there was no interference with patients' ability to start physiotherapy, allowing for optimal functional recovery. Quantifying pain is a significant outcome for both clinicians and families in the sphere of CP and SDR. This knowledge can be used as a baseline for developing a best-practice pain management protocol following SDR surgery, as well as offering improvements to our own protocol. We also hope this information can provide reassurance to patients' families and enhance their understanding of SDR surgery and the postoperative period.

Contributors Conception and design: IGA, NB, SP. Administrative support: NB, MEA-L, SP. Provision of study material or patients: RJ, JL, SP. Collection and assembly of data: IGA. Data analysis and interpretation: IGA, RJ, JL, SP. Manuscript writing: all authors. Final approval of manuscript: all authors. SP accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. The ethics approval was obtained at the Sydney Children's Hospital Network, HREC/16/SCHN/383. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. All data relevant to the study are included in the article or uploaded as supplementary information.

ORCID iDs
Isabel G Adams http://orcid.org/0000-0001-5699-3759
Mohamed E Abdel-Latif http://orcid.org/0000-0003-4306-2933

REFERENCES

1 The Australian Cerebral Palsy (ACPR) Group. Report of the Australian cerebral palsy register birth years 1995-2012; 2018. Available: https://cpregister.com/wp-content/uploads/2019/02/Report-of-the-Australian-Cerebral-Palsy-Register-Birth-Years-1995-2012.pdf
2 Rosenbaum P, Paneth N, Leviton A, *et al*. The definition and classification of cerebral palsy. *Dev Med Child Neurol* 2007;49:1–44.
3 Vitrikas K, Dalton H, Breish D. Cerebral palsy: an overview. *Am Fam Physician* 2020;101:213–20.
4 Aquilina K, Graham D, Wimalasundera N. Selective dorsal rhizotomy: an old treatment re-emerging. *Arch Dis Child* 2015;100:798–802.
5 Graham D, Aquilina K, Cawker S, *et al*. Single-level selective dorsal rhizotomy for spastic cerebral palsy. *J Spine Surg* 2016;2:195–201.
6 Ailon T, Beauchamp R, Miller S, *et al*. Long-term outcome after selective dorsal rhizotomy in children with spastic cerebral palsy. *Childs Nerv Syst* 2015;31:415–23.
7 Lewis J, Bear N, Baker F, *et al*. Australian children undergoing selective dorsal rhizotomy: protocol for a national Registry of multidimensional outcomes. *BMJ Open* 2019;9:e025093.
8 Munger ME, Aldahondo N, Krach LE, *et al*. Long-term outcomes after selective dorsal rhizotomy: a retrospective matched cohort study. *Dev Med Child Neurol* 2017;59:1196–203.
9 Tedroff K, Hägglund G, Miller F. Long-term effects of selective dorsal rhizotomy in children with cerebral palsy: a systematic review. *Dev Med Child Neurol* 2020;62:554–62.
10 McLaughlin J, Bjornson K, Temkin N, *et al*. Selective dorsal rhizotomy: meta-analysis of three randomized controlled trials. *Dev Med Child Neurol* 2002;44:17–25.
11 Ingale H, Ughratdar I, Muquit S, *et al*. Selective dorsal rhizotomy as an alternative to intrathecal baclofen pump replacement in GMFCS grades 4 and 5 children. *Childs Nerv Syst* 2016;32:321–5.
12 Hatef J, Smith LGF, Veneziano GC, *et al*. Postoperative pain protocol in children after selective dorsal rhizotomy. *Pediatr Neurosurg* 2020;55:181–7.
13 Hesselgard K, Reinstrup P, Stromblad LG, *et al*. Selective dorsal rhizotomy and postoperative pain management. A worldwide survey. *Pediatr Neurosurg* 2007;43:107–12.
14 Moore RP, Wester T, Sunder R, *et al*. Peri-operative pain management in children with cerebral palsy: comparative efficacy of epidural vs systemic analgesia protocols. *Paediatr Anaesth* 2013;23:720–5.
15 Nimmo SM, Foo ITH, Paterson HM. Enhanced recovery after surgery: pain management. *J Surg Oncol* 2017;116:583–91.
16 Ostojic K, Paget SP, Morrow AM. Management of pain in children and adolescents with cerebral palsy: a systematic review. *Dev Med Child Neurol* 2019;61:315–21.
17 Yoo JS, Ahn J, Buvanendran A, *et al*. Multimodal analgesia in pain management after spine surgery. *J Spine Surg* 2019;5(Suppl 2):S154–9.
18 Devin CJ, McGirt MJ. Best evidence in Multimodal pain management in spine surgery and means of assessing postoperative pain and functional outcomes. *J Clin Neurosci* 2015;22:930–8.
19 Geiduschek JM, Haberkern CM, McLaughlin JF, *et al*. Pain management for children following selective dorsal rhizotomy. *Can J Anaesth* 1994;41:492–6.
20 Blackman JA, Svensson CI, Marchand S. Pathophysiology of chronic pain in cerebral palsy: implications for pharmacological treatment and research. *Dev Med Child Neurol* 2018;60:861–5.
21 Pao LP, Zhu L, Tariq S, *et al*. Reducing opioid usage: a pilot study comparing postoperative selective dorsal rhizotomy protocols. *J Neurosurg Pediatr* 2019;2019:1–6.
22 Duffy EA, Hornung AL, Chen BP-J, *et al*. Comparing short-term outcomes between conus medullaris and cauda equina surgical techniques of selective dorsal rhizotomy. *Dev Med Child Neurol* 2021;63:336–42.