

# Current Trends in Pediatric Spine Deformity Surgery: Multimodal Pain Management and Rapid Recovery

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## Abstract

**Study Design:** Narrative review.

**Objectives:** The purpose of this article is to perform a review of the literature assessing the efficacy of opioid alternatives, multimodal pain regimens, and rapid recovery in pediatric spine surgery.

**Methods:** A literature search utilizing PubMed database was performed. Relevant studies from all the evidence levels have been included. Recommendations to decrease postoperative pain and expedite recovery after posterior spinal fusion in adolescent idiopathic scoliosis patients have been provided based on results of studies with the highest level of evidence.

**Results:** Refining perioperative pain management to lessen opioid consumption with multimodal regimens may be useful to decrease recovery time, pain, and complications. Nonsteroidal anti-inflammatory drugs, acetaminophen, gabapentin, neuraxial blockades, and local anesthesia alone offer benefits for postoperative pain management, but their combination in multimodal regimens and rapid recovery pathways may contribute to faster recovery time, improved pain levels, and lower reduction in total opioid consumption.

**Conclusion:** A rapid recovery pathway using the multimodal approach for pediatric scoliosis correction may offer superior postoperative pain management and faster recovery than traditional opioid only pain protocols.

## Keywords

multimodal analgesia, NSAIDs, acetaminophen, intrathecal analgesia, epidural analgesia, gabapentin, pediatric spine surgery

## Introduction

Postoperative pain after posterior spinal fusion (PSF) for adolescent idiopathic scoliosis (AIS) has recently seen changing trends in management. By using effective postoperative pain regimens, surgeons can significantly improve patient satisfaction, facilitate early mobilization, promote oral intake, lower postoperative pain, and shorten length of hospital stay.<sup>1-3</sup> Customary practice utilized opioids as its cornerstone, but this practice is associated with adverse side effects.<sup>3,4</sup> These complications delay patient mobilization and lengthen patient stay thus encouraging a transition to a more balanced regimen. Multimodal pain control in orthopedic surgery has been especially well described in adult reconstruction literature and studies have shown reduced opioid consumption, improved pain control, and shorter hospital stays.<sup>5</sup> Kurd et al<sup>6</sup> provided

a comprehensive review of the literature and found a growing body of evidence supporting the use of multimodal analgesia in adult spine surgery; however, the role of multimodal analgesia in pediatric spine surgery is not as well established. The purpose of this article was to review current literature supporting multimodal pain regimens and rapid recovery pathways in AIS surgery.

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**Table 1.** NSAIDs and Acetaminophen Studies.

Study	Design	No. of Patients	Drug and Administration
Munro et al (2002) <sup>10</sup>	Prospective DB RCT	35 (11-17 years)	0.2 mg/kg ketorolac or placebo 6 hours after surgery for 36 hours with PCA
Vitale et al (2003) <sup>11</sup>	RR	208 (~ 13.4 years)	~0.5 mg/kg IV ketorolac every 6 hours for 2-3 days starting 24-28 hours postoperation or no ketorolac
Hiller et al (2012) <sup>12</sup>	DB RCT	36 (10-18 years)	30 mg/kg IV acetaminophen (90 mg/kg/d) or 0.9% NaCl postsurgery, then twice at 8-hour intervals
Reuben et al (2005) <sup>13</sup>	RR	434 adults	Perioperative daily dose of 20-240 mg ketorolac, 200-600 mg celecoxib, 50 mg rofecoxib, or no NSAIDs for 5 days after spinal fusion
Ibach et al (2015) <sup>14</sup>	RR	44 (~ 14 years)	IV acetaminophen every 6 hours for 24 hours or oral acetaminophen after surgery, including intrathecal morphine

Abbreviations: DB, double blind; IV, intravenous; NSAIDs, nonsteroidal anti-inflammatory drugs; PCA, patient-controlled analgesia; RCT, randomized controlled trial; RR, retrospective review.

## Multimodal Pain Management

Expedient recovery of patients following posterior spinal fusion is intimately related to pain control and mobilization. Conceptually, a multimodal approach to pain control stems from the ills associated with opioid medications. There is variability in the medications utilized in multimodal approaches across institutions. In this section, we review several cornerstone medications that have been associated with multimodal pain regimens, including nonsteroidal anti-inflammatory drugs (NSAIDs), intravenous (IV) acetaminophen, gabapentin, epidurals, intrathecal morphine, and local medications.

## Opioids

Opioids remain a mainstay in postoperative pain control after AIS surgery. Although effective in pain control, they are associated with well-established side effects. These adverse effects include the following: somnolence, pruritis, respiratory depression, ileus, nausea, and urine retention.<sup>7</sup> Currently, there is no consensus on what dose of opioid is the optimum dose to control postoperative pain, but controlling pain while minimizing opioid administration is a ubiquitous goal. Traditionally, intravenous opioids were the primary medication for pain relief after PSF for AIS; however, authors have described new protocols to minimize opioid use. In a recent best practice guideline for postoperative care after PSF for AIS, Fletcher et al<sup>8,9</sup> describe a protocol in which patients are prescribed intravenous morphine-based patient-controlled analgesia (PCA) for 1 day postoperatively. The PCA is then discontinued and patients are transitioned to oral narcotics. These authors attribute a decrease in intravenous opioids as a factor in quicker rehabilitation and recovery for their patients postoperatively.

The duration of oral narcotic prescription after discharge has not been studied and is variable based on surgeon preference. At our institution, patients are prescribed oral hydrocodone/acetaminophen 5/325 mg every 4 hours as needed for pain for 7 days after discharge. Patients are encouraged to transition to oral acetaminophen or ibuprofen after the 7-day period. Further studies are needed to create a guideline for appropriate prescribing of opioids after discharge.

## Nonsteroidal Anti-Inflammatory Drugs

NSAIDs have shown promise in reducing postoperative opioid requirements in the pediatric population (Table 1). Michelet et al<sup>15</sup> performed a meta-analysis of the use of NSAIDs for pediatric postoperative pain in general pediatric surgery and found that perioperative NSAID administration significantly reduced opioid consumption and nausea. Hayes et al<sup>16</sup> surveyed 61 anesthesiologists from international academic pediatric hospitals and found that 59% routinely use NSAIDs in the postoperative period following pediatric scoliosis surgery. In this survey, IV ketorolac was the most commonly reported agent.<sup>16</sup> Munro et al<sup>10</sup> performed a prospective randomized double-blinded placebo-controlled trial studying the effect of low-dose ketorolac following PSF. Patients who received ketorolac had significantly lower pain scores on postoperative days (POD) 1 and 2 and consumed less morphine in the postanesthesia care unit through POD 2. Patients in the ketorolac group also tolerated activity better on POD 1 than the patients in the control group. There was no difference in the incidence of pruritus, nausea, vomiting or constipation.<sup>10</sup>

Despite the benefits, NSAID use has not been unanimously adopted in spinal fusion surgeries because of the potential risk of pseudoarthrosis and postoperative bleeding.<sup>17,18</sup> Two key studies evaluated these risks but did not find the same risks in pediatric populations. Sucato et al<sup>19</sup> performed a retrospective review comparing patients who had postoperative ketorolac and those who did not following PSF for AIS. The overall incidence of pseudoarthrosis was 2.5% for all patients. There was no difference in the incidence of pseudoarthrosis comparing a patient receiving ketorolac (1.9%) and one who did not (3.1%). They subsequently concluded that ketorolac may be useful to supplement pain management postoperatively in AIS surgery and did not increase the risk of pseudoarthrosis.<sup>19</sup>

Additionally, the risk of postoperative bleeding following NSAID administration has not been validated. Vitale et al<sup>11</sup> performed a retrospective review to determine whether there is any association between the use of ketorolac and postoperative complications in a group of children who underwent scoliosis surgery. These investigators looked at postoperative

**Table 2.** Neuromodulatory Agent Studies.

Study	Design	No. of Patients	Drug and Administration
Mayell et al (2014) <sup>21</sup>	RCT	44 (10-17 years)	600 mg gabapentin 1 hour before surgery
Rusy et al (2010) <sup>22</sup>	DB RCT	63 (9-18 years)	Preoperative 15 mg/kg gabapentin with 5 mg/kg gabapentin 3 times a day for 5 days with PCA
Choudhry et al (2017) <sup>23</sup>	RR	127 children	Morphine and PCA, PCA + gabapentin, or PCA + gabapentin + clonidine

Abbreviations: DB, double blind, PCA, patient-controlled analgesia; RCT, randomized controlled trial; RR, retrospective review.

transfusion and reoperation rates for any reason, including pseudoarthrosis. They found that out of 208 children undergoing spine surgery, postoperative use of ketorolac did not significantly increase the incidence of blood transfusion and reoperation for any reason. They concluded that the use of ketorolac was safe in the postoperative period following pediatric scoliosis surgery.<sup>11</sup>

### Intravenous Acetaminophen

IV acetaminophen has shown promise in reducing opioid requirements and decreasing postoperative pain in adult studies; however, evidence in pediatric patients has been lacking. Oral and intravenous acetaminophen are beneficial for their anti-inflammatory, antipyretic, and analgesic effects.<sup>20</sup> Hiller et al<sup>12</sup> performed a randomized, placebo-controlled, double-blind study to evaluate the effect of IV administered acetaminophen on postoperative pain in children and adolescents undergoing surgery for idiopathic scoliosis or spondylolisthesis (Table 1). Patients in this study were given 30 mg/kg of IV acetaminophen or normal saline postoperatively at 8-hour intervals. The authors found that IV acetaminophen administered at 90 mg/kg/d as an adjuvant to oxycodone improved analgesia, but did not diminish oxycodone consumption 24 hours postoperatively after major spine surgery in children and adolescents.<sup>12</sup> Considering the relative safety of IV acetaminophen, using it for controlling postoperative pain may be beneficial; but further studies are needed to determine its efficacy.

### Gabapentin

The neuromodulatory agent gabapentin is an antiepileptic medication thought to improve pain through reduction of sensory nerve excitability. Studies have demonstrated efficacy in the following adult spine surgery, but results in pediatric spine deformity population have been mixed (Table 2). Mayell et al<sup>21</sup> performed a randomized control trial to study the effects of a single preoperative dose of gabapentin 600 mg versus placebo on postoperative morphine consumption in the first 24 hours after surgery. They found that a single preoperative dose of gabapentin was not associated with a significant difference in opioid consumption or pain scores in adolescents undergoing idiopathic scoliosis surgery.<sup>21</sup> Rusy et al<sup>22</sup> performed a randomized double-blind controlled trial to determine the effect of gabapentin on acute pain in the immediate

postoperative period, specifically morphine consumption and opioid side effects, in the pediatric spinal fusion patient with idiopathic scoliosis. Patients in this study were randomized to receive a preoperative dose of oral gabapentin at 15 mg/kg followed by 5 mg/kg of oral gabapentin 3 times daily postoperatively or a placebo. They found that preoperative gabapentin with continued administration is effective in reducing morphine consumption and pain scores in the early postoperative period. Benefits were observed for the immediate postoperative period through day 2, but no benefits were observed after POD 2. No significant differences in opioid side effects were found between the gabapentin and placebo groups.<sup>22</sup> These studies show that preoperative and postoperative gabapentin may help reduce immediate postoperative opioid consumption, but no benefit after the immediate postoperative period.

### Neuraxial Blockades—Epidural Analgesia

Efficacy of neuraxial blockade for postoperative pain control after adult spine surgery has been demonstrated with level 1 evidence, but efficacy or safety have not been shown to be superior compared with IV medication after pediatric scoliosis surgery. There have been several retrospective studies assessing the efficacy of epidural analgesia after pediatric spine surgery (Table 3). Hong et al<sup>32</sup> retrospectively reviewed the charts of 56 children who had epidural analgesia after AIS surgery. They found that none of these children had any neurologic or respiratory adverse event, ambulation occurred on PODs 1 or 2, and that mean length of stay was 3.95 days. They concluded that epidural analgesia was a safe and effective way to control postoperative pain after AIS surgery.

Cassady et al<sup>25</sup> performed a prospective randomized control trial comparing the effects of continuous epidural anesthesia (CEA) with PCA after posterior spinal fusion for AIS. These investigators randomized 33 patients into either the CEA or PCA group and measured pain intensity with self-reported visual analogue scale (VAS), postoperative resumption of bowel sounds, liquid intake, and adverse effects. They found that there was no significant difference in VAS scores, liquid intake, or adverse effects; however, return of bowel sounds was significantly faster in the CEA group. The authors concluded that both CEA and PCA are comparable in terms of efficacy and safety.

O'Hara et al<sup>33</sup> also performed a prospective double-blinded randomized controlled trial studying the effect of epidural

**Table 3.** Epidural Analgesia Studies.

Study	Design	No. of Patients	Drug and Administration
Lavelle et al (2010) <sup>24</sup>	RR	55 adolescents	0.1% bupivacaine with fentanyl 2 µg/mL DCEA
Cassady et al (2000) <sup>25</sup>	RCT	23 (11-18 years)	0.125% bupivacaine in 0.0025 mg/mL fentanyl SCEA and PCA
Gall et al (2001) <sup>26</sup>	Prospective DB RCT	30 (9-19 years)	2 or 5 µg/kg IT morphine with PCA
Cohen et al (2017) <sup>27</sup>	Prospective DB RCT	71 (8-17 years)	7.5 µg/kg IT morphine or 0.15 mg/kg EREM
Van Boerum et al (2000) <sup>7</sup>	RR	127 children	0.1% bupivacaine SCEA with morphine sulfate at 0.05 mg morphine/kg/h. Additional doses at 0.03 mg/kg/h
Shaw et al (1996) <sup>28</sup>	RR	71 (13.6 years)	0.0625%-0.125% bupivacaine SCEA in morphine or fentanyl
Ekotodramis et al (2002) <sup>29</sup>	Case series	23 (12-19 years)	0.0625% bupivacaine DCEA initial bolus (8 mL for >50 kg patients and 5 mL for <50 kg patients). After 0.0625% bupivacaine continuous infusion with 2 µg/mL fentanyl and 3 µg/mL clonidine at 10 mL/h
Tobias et al (2001) <sup>30</sup>	Cohort	14 (5-17 years)	1 µg/kg hydromorphone DCEA. Succeeded by 0.1% ropivacaine and 20 µg/mL hydromorphone continuous infusion
Klatt et al (2013) <sup>31</sup>	RCT	66 (10-21 years)	IV-PCA or 0.1% bupivacaine in 2 µg/mL fentanyl SCEA, DCEA

Abbreviations: DB, double blind; DCEA, double catheter epidural analgesia; EREM, extended release epidural morphine; IT, intrathecal; IV, intravenous; PCA, patient-controlled analgesia; RCT, randomized controlled trial; RR, retrospective review; SCEA, single catheter epidural analgesia.

versus intravenous analgesia following PSF for AIS. They randomized 31 patients into 3 groups: a low-dose epidural group, high-dose epidural group, and a placebo group. They found no difference in postoperative pain control, oral intake, bowel sounds, ambulation, or length of stay between the 3 groups.<sup>33</sup> They concluded that there was no difference in outcomes when using epidural or intravenous analgesia after PSF in adolescents.

### Intrathecal Morphine

Intrathecal morphine has shown promise in decreasing intraoperative blood loss and opioid requirement after AIS surgery. Blackman et al<sup>34</sup> administered intrathecal morphine to 33 pediatric patients undergoing PSF and found that the mean duration of postoperative pain relief was 18.8 hours. They concluded that intrathecal morphine administration was effective in controlling postoperative pain after AIS surgery; however, this study did not include a control group. Goodzari<sup>35</sup> evaluated the efficacy of lumbar intrathecal morphine and intrathecal sufentanil administration preoperatively and compared it with intrathecal sufentanil administration alone in 80 pediatric patients undergoing PSF. He found that intraoperative blood loss was almost 50% lower in the intrathecal morphine group than in the control group. He also found that the need for postoperative analgesia was delayed by 14.5 hours in the intrathecal morphine group whereas the control group needed postoperative analgesia immediately. Additionally, postoperative mobilization was tolerated better in the intrathecal morphine group.<sup>35</sup> Gall et al<sup>26</sup> studied the effect of intrathecal morphine in 30 pediatric patients undergoing PSF. They compared a high dose of intrathecal morphine (5 µg) with a lower dose of intrathecal morphine (2 µg) and a saline control group. They found that intraoperative blood loss was lower in the high-dose group than in the low-dose and control groups.<sup>26</sup> They also found that the first 24-hour morphine consumption by PCA was lower in the intrathecal morphine groups compared with the control group.

**Table 4.** Local Anesthesia—Bupivacaine Studies.

Study	Design	No. of Patients	Drug and Administration
Ross et al (2011) <sup>36</sup>	RR	244 (10-18 years)	Continuous infusion of 0.5% bupivacaine at 4 mL/h via one 10-inch soaker or two 5-inch soakers for ~100 hours after surgery

Abbreviation: RR, retrospective review.

A noteworthy concern from neuraxial blockades, especially intrathecal use, is respiratory depression, which is potentially fatal.<sup>6</sup> In the study by Blackman et al,<sup>34</sup> the authors found that respiratory depression was noted in 8 out of the 33 patients in their study, but they attribute this to the large volume of fluid used for the infusion rather than the intrathecal morphine itself. Goodzari<sup>35</sup> did not report any incidence of respiratory depression in the 80 patients in their study, though they found that carbon dioxide levels were higher in the intrathecal morphine group compared with the control group. Gall et al<sup>26</sup> did not find any statistical difference in the adverse effects between the high-dose, low-dose, or control groups. Intrathecal morphine, therefore, is a safe and effective way to control early postoperative pain following PSF in pediatric patients.<sup>26,34,35</sup>

### Local Anesthesia—Bupivacaine

Bupivacaine provides analgesia by infusion through catheters in paraspinous muscle, subfascial area, or subcutaneous areas adjacent to spinal instrumentation. There has been only 1 study to date evaluating the use of bupivacaine in pediatric spine surgery (Table 4). Ross et al<sup>36</sup> stated that continuous basal infusion of morphine was required in 85.2% of patients without bupivacaine and only 32.6% of patients with continuous bupivacaine 1 day after surgery (18.9 vs 26.4 mg). The depth of catheter insertion did not influence postoperative opioid use, but ideal depth needs future investigation. Pain scores were

equivalent in treatment and placebo groups at 6, 12, and 24 hours postoperatively but was significantly higher by 1 point at 18 hours.

## The Rapid Recovery Pathway

In recent years, the immediate postoperative period has been a primary focus of change in pain management for patients undergoing orthopedic surgery, including PSF for AIS. Traditional postoperative regimens often involved 24 hours of bed rest or limited activity; however, there have been studies reporting early mobilization in combination with multimodal analgesia may decrease hospital stay. Multimodal analgesia incorporates the assortment of nonopioid agents previously discussed in this review. Given at predetermined intervals, these agents act synergistically with opioids to accelerate recovery time, lower pain levels, decrease the incidence of adverse effects, and reduce total opioid consumption. Multimodal practices have received praise in orthopedic procedures, especially joint arthroplasty<sup>5,37</sup>; but there is little research on pediatric scoliosis correction. This treatment promotes faster recovery and early mobilization associated with the decrease in opioid requirements.

In a quality improvement project at the Children's Hospital of Philadelphia, Muhly et al<sup>38</sup> standardized a rapid recovery pathway to promote early mobilization after posterior spinal fusion for AIS. In this pathway, patients were started on PCA on POD 0. On POD 1, they were taken off the PCA and started on oral pain medication with intravenous hydromorphone for breakthrough pain. Oral diazepam and gabapentin are also included in the oral regimen. IV ketorolac was added at the discretion of the surgeon. Ambulation was started three times daily. On POD 2, the oral pain regimen and physical therapy for ambulation three times daily is continued. On POD 3, discharge is finalized once the patient is tolerating oral analgesia, has clearance from physical therapy, and is tolerating a diet. After implementing this pathway, they noticed a significant decrease in hospital stay, from 5 days to 4 days. They also noted a decrease in numerical pain score on PODs 0 to 2 with the rapid recovery pathway implementation. These authors concluded that implementing this rapid recovery pathway reduced time to functional recovery and maintained effective analgesia postoperatively following PSF for AIS.

Fletcher et al<sup>8</sup> published a study in which they retrospectively compared 105 patients treated with an accelerated discharge (AD) pathway to 45 patients treated with a traditional discharge (TD) pathway. The TD pathway consisted of transition from PCA to oral pain medication on POD 3, mobilization with physical therapy once on POD 1, transition to solid diet on POD 2, and discharge on PODs 4 to 5. The AD pathway consisted of transition from PCA to oral medication on POD 1, mobilization with physical therapy twice-daily starting POD 1, transition to a solid diet on POD 1, and discharge PODs 2 to 3. They retrospectively compared the following characteristics between the 2 groups: Cobb angles, surgical times, estimated blood loss, length of stay, readmissions, and wound

complications. They found that length of stay was 48% lower in patients treated with the AD pathway compared to the TD pathway without any difference in complications. In another study looking at financial implications of this AD pathway, Fletcher et al<sup>9</sup> found that the AD pathway led to a small but significant decrease in hospital cost when compared with the TD pathway. These authors concluded that the AD pathway not only may decrease hospital stay, but total hospital cost associated with PSF for AIS as well.<sup>9</sup>

At our institution, we modeled our postoperative regimen after that established by Fletcher et al.<sup>8,9</sup> Our patients are started on PCA on POD 0. At 6 AM on POD 1, the PCA is discontinued and patients are started on oral hydrocodone/acetaminophen and diazepam with IV morphine for breakthrough pain. Additionally, on POD 1, our patients ambulate 3 times daily and the urinary catheter is removed. Patients are started on a solid diet on POD 1 or 2 once bowel sounds are confirmed. They are discharged on POD 3 pending pain control on oral medication, adequate mobilization, and toleration of a diet. We have not found a difference in mobilization initiated with physical therapy as opposed to nursing staff. After transitioning to an accelerated mobilization model 1½ years ago, we have noted a significant decrease in length of stay with over 90% discharged on POD 3 as opposed to POD 4. We are currently investigating our accelerated protocol in comparison to the traditional protocol and have also noted patient expectations and nursing staff buy-in as cornerstones to successful implementation of an accelerated protocol.

## Summary

Pediatric scoliosis patients are a unique population as they often enter the hospital generally healthy and functional but find themselves leaving in a debilitated condition. As such, the employment of an effective pain management protocol should be a priority. Although a consensus has not been reached regarding on a postoperative protocol, earlier transition to oral pain medication, earlier ambulation, and earlier discharge are current trends in the perioperative care of AIS patients undergoing posterior spinal fusion.<sup>8</sup> Studies have shown that managing pain with adjuvants to opioid treatment may provide good outcomes by lowering opioid use, shortening length of stay, and increasing patient satisfaction. This has the added benefit of a quicker return to mobilization after surgery, which accelerates recovery allowing ambulation to begin sooner. Although NSAIDs, acetaminophen, neuraxial blockades, local anesthesia, and neuromodulatory agents alone offer many benefits, more emphasis should be laid on utilizing them in multimodal practices to yield the best result. Multimodal analgesic regimens may be used as part of a rapid recovery pathway to facilitate faster recovery in patients undergoing PSF for AIS.


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