MULTIMODAL ANALGESIA PRACTICES IN CERVICAL SPINAL FUSIONS UTILIZING REMIFENTANIL

by

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ABSTRACT

AMY ADAMS. Multimodal Analgesia Practices in Cervical Spinal Fusions Utilizing Remifentanil. (Under the direction of DR. KELLY POWERS, PHD, RN)

This quality improvement project sought to identify current usage of multimodal analgesics in cervical spinal fusion procedures utilizing remifentanil infusions. Guided by provider judgment, the choice of specific pain medication combinations can impact patients' self-reported pain scores in the postoperative recovery room (PACU). While many options are available, commonly used intraoperative medications with analgesic properties include fentanyl, hydromorphone, methadone, ketamine, dexmedetomidine, lidocaine infusions, and magnesium infusions. The literature review supported the use of multimodal analgesia to combat opioid-induced hyperalgesia (OIH) associated with remifentanil. After conducting a retrospective chart review focused on cervical spinal fusion surgeries for 50 patients at a level one academic medical center, postoperative pain scores and pain medication administration were examined for patients who received intraoperative remifentanil infusion in combination with other analgesics.

Linear regression identified no significant associations between the number of intraoperative multimodals and the number of doses of pain medications in PACU ($b = 0.27$, $t = 1.00$, $p = 0.322$) or the average pain scores in PACU ($b = 0.31$, $t = 1.28$, $p = 0.207$). Pearson's r correlations found that none of the individual multimodals were associated with pain medication administration or pain scores in PACU. Although there was a lack of statistically significant findings, it was found that nurse anesthetists were employing a multimodal approach to analgesia and, furthermore, tailoring the anesthetic to each patient's needs. More study of specific uses of different multimodal analgesics in combination with remifentanil could be beneficial to clinical practices. More research and projects need to be conducted to see if the patient outcome data and the literature agree – that multimodal analgesia can combat OIH associated with remifentanil.

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DEDICATION

This project is dedicated to my daughter, Emma Louise. I have only made it this far because of you, not in spite of you. Thank you for cheering me on to the finish. I love you, forever and always.

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LIST OF ABBREVIATIONS

ACCF	Anterior Cervical Corpectomy and Fusion
ACDF	Anterior Cervical Discectomy and Fusion
ALIF	Anterior Lumbar Interlaminar Fusion
ASA	American Society of Anesthesiologists
CRNA	Certified Registered Nurse Anesthetist
CVP	Central Venous Pressure
EHR	Electronic Health Record
ELGGN	European Low-Grade Glioma Network
EMG	Electromyography
HR	Heart Rate
ICU	Intensive Care Unit
IONM	Intraoperative Neuromonitoring
IRB	Institutional Review Board
IV-PCA	Intravenous Patient-Controlled Analgesia
LOS	Length of Stay
MAP	Mean Arterial Pressure
MAR	Medication Administration Record
MDA	Medical Doctor of Anesthesiology
MEP	Motor Evoked Potentials
MMPC	Multimodal Pain Control
NMDA	N-Methyl-D-Aspartate
NRS	Numerical Rating Scale

OIH	Opioid-Induced Hyperalgesia
PACU	Post Anesthesia Care Unit
PCDF	Posterior Cervical Decompression and Fusion
PDSA	Plan-Do-Study-Act
POD	Postoperative Day
PONV	Postoperative Nausea and Vomiting
pTEAS	Perioperative Transcutaneous Electrical Acupoint Stimulation
QoR	Quality of Recovery
RCR	Retrospective Chart Review
REDCap	Research Electronic Data Capture
SSEP	Somatosensory Evoked Potentials
SVR	Systemic Vascular Resistance
TIVA	Total Intravenous Anesthetic
TKA	Total Knee Arthroplasty
TUGOR	Transvaginal Ultrasound Guided Oocyte Retrieval
VAS	Visual Analogue Scale
VATS	Video Assisted Thoracoscopic Surgery

CHAPTER I: INTRODUCTION AND BACKGROUND

Remifentanil is a potent, ultra-short-acting opioid analgesic used for pain control and sedation during surgical procedures (Flood et al., 2015). Remifentanil's fast onset and short-acting profile makes it an ideal choice in surgical cases requiring complete stillness without the use of paralytic drugs or with high risk for neurological sequelae (Flood et al., 2015). Complex and longer in duration, spinal fusion surgeries of the cervical, thoracic, or lumbar segments are associated with severe postoperative pain requiring tight pain control as well as intraoperative stillness without the use of paralytics (Waelkens et al., 2021). Hence, remifentanil is frequently administered during surgery by anesthesia providers via continuous infusion in this subspecialty. Leading textbook guidance states that due to its quick metabolism, the remifentanil infusion should not be discontinued before one or more longer-acting analgesic medications are administered to adequately manage postoperative pain (Flood et al., 2015). Numerous medications with analgesic properties are available, with the basis of administration considering multiple factors, including patient comorbidities, hemodynamic parameters, and surgical requirements. A second guiding text emphasizes the need for developing and planning for an adequate analgesic therapy in the patient's postoperative period (Nagelhout & Elisha, 2018). More recently, there has been increased use of intraoperative multimodal analgesics to lessen the amount of narcotics required. It is important to examine the use of multimodal analgesics with remifentanil infusions to establish guidelines, as none currently exist.

Problem Statement

Spurred by the continual pursuit of improving healthcare quality, analysis of the current practices of anesthetists providing care in cervical, thoracic, and lumbar spinal fusions can provide insight on best practices and patient outcomes. Independent to the duration of the

infusion, the context sensitive half-life of remifentanil is approximately seven minutes (Nagelhout & Elisha, 2018). Anesthesia providers can modify anesthetic techniques based on patient needs, facility guidelines, medication availability, and user preference. According to textbook recommendations, achieving a suitable level of pain management before discontinuing the remifentanil infusion is advised to effectively address postoperative discomfort (Flood et al, 2015). However, given the individual variability in drug metabolism, some providers choose to conservatively administer pain medication before awakening patients due to reports of delayed remifentanil offset, increasing the risk of respiratory depression and prolonged patient emergence (Bateman et al., 2021). The timing, amount, and choice of opioid may increase the risk for acute opioid tolerance or a hyperalgesic state (Yu et al., 2016). Other providers may choose a multimodal or non-narcotic approach for pain management, utilizing adjuncts such as ketamine, dexmedetomidine, lidocaine infusions, and/or magnesium sulfate infusions (Flood et al., 2015). Recent research has supported the use of pain medications affecting multiple receptors, yet inadequate evidence exists to recommend therapy guidelines for complex spinal procedures (Waelkens et al., 2021). Given the changeability of anesthetic approaches, investigating the current practices of analgesic management may provide insight on techniques for superior pain control and improved patient outcomes.

Purpose of the Project

It is important to examine how analgesic administration in spinal fusions using a remifentanil infusion affects patient outcomes. The need for examination is due to serious potential adverse effects, such as hyperalgesia or insufficient pain control, both of which are associated with increased length of stay (LOS) and inflated cost (Ogura et al., 2020). Suhitharan et al. (2018) noted that the hyperalgesia effect of remifentanil may require increased

postoperative opioid use, which can affect care costs as well as patient outcomes. In a study analyzing head and neck surgeries, 45.9% of patients that received remifentanil (as well as a morphine bolus prior to remifentanil infusion discontinuation) required opioids in the post anesthesia care unit (PACU) and spent an average of 77.5 minutes in recovery (Suhitharan et al., 2018). A mere 22.5% of those who received solely morphine and/or fentanyl intraoperatively required extra dosages postoperatively and spent an average of 65 minutes in recovery (Suhitharan et al., 2018). This study demonstrates that even with best practice, remifentanil may still be associated with increased need for postoperative medications, a longer PACU LOS, and higher overall care costs. A second study analyzed how multimodal pain control (MMPC) impacted postoperative opioid administration in anterior lumbar interlaminar fusion (ALIF) and posterior fusion procedures, finding a 62% reduction in narcotic administration after surgery (Ogura et al., 2020). Therefore, identifying correlations between the administration of certain analgesic medications and lower pain scores and reduced pain medication administration in the PACU may suggest changes that can improve patient outcomes. Patient outcome data is needed to be able to analyze anesthesia provider practices at the project site.

Numerous stakeholders benefit from optimization of medication efficacy and improvement in patient outcomes and costs. Nurse anesthetists (CRNAs) and anesthesiologists (MDAs) may see an improvement in postoperative complications and patient satisfaction scores due to adequate pain control. Recovery nurses in the PACU may spend less time administering medications that require heightened monitoring and have improved bed turnover. Striving to perform patient-centered care with less postoperative pain medication administration would ultimately benefit the budget and reduce hospital expenses. Finally, patients may benefit by

experiencing faster rehabilitation, reduced postoperative pain, and overall positive experiences after a notably painful procedure.

This quality improvement (QI) project focused on cervical spinal fusions. However, it is part of a larger QI project also encompassing both thoracic and lumbar spinal fusions (Baek, 2025; George, 2025). Remifentanil infusions are used frequently, but not consistently, for intraoperative analgesia during these surgeries. Procedures involving spinal manipulation require vigilance, specific vital sign parameters, and continual neuromonitoring through somatosensory evoked potentials (SSEPs), motor evoked potentials (MEPs), or electromyography (EMG) (Cottrell & Patel, 2017). Because of this, anesthesia providers often have limitations on the anesthetic gasses and/or neuromuscular blocking agents they can utilize (Cottrell & Patel, 2017). Remifentanil has proven to be a dependable alternative, as it only mildly alters neural pathway recordings and allows for the sedated patient to regain consciousness during a predictable timeframe (D'Onofrio et al., 2023). While analgesic administration with a remifentanil infusion is determined by provider preference, supplemental pain medications included in this practice analysis were fentanyl, hydromorphone, methadone, ketamine, dexmedetomidine, lidocaine infusions, and magnesium infusions.

PICO Question

In this retrospective chart review, the goal was to analyze current practices and associated pain outcomes of multimodal analgesic administration during spinal fusion procedures utilizing remifentanil infusions. The guiding PICO question was: In patients undergoing cervical spinal fusions at a level one academic medical center (P), what are the current practices of multimodal analgesic administration and how do different analgesic medication combinations (C) administered in spinal fusion procedures utilizing remifentanil infusions (I) affect self-reported

pain scores in the PACU (O)? The primary methodology was a chart review of medical records of patients who underwent spinal fusions at the project site between January 2023 to June 2024 and transitioned to the PACU.

Postoperative pain scores using the Numerical Rating Scale (NRS) were collected in the chart review using the facility's established pain assessment protocol. Utilizing the NRS, patients are asked to rate pain on a numerical scale ranging from 0 (representing no pain) to 10 (signifying the worst pain ever experienced) (van Dijk et al., 2015). Along with demonstrating neurological and hemodynamic stability, patients must verbalize adequate pain control before discharge from the PACU, providing a direct correlation between pain levels and length of in-hospital rehabilitation. A secondary postoperative outcome was the need for pain medications in the PACU (Flood et al., 2015).

To analyze patient postoperative outcomes, the use of remifentanil was examined in cervical spinal fusions performed at a level one academic medical center. Boasting 53 operating rooms, this hospital is equipped to manage trauma cases and specializes in many unique conditions, such as congenital malformations or organ transplants. Given this location’s size, influence, and broad range of medication availability, examining postoperative patient outcomes data at this project site is vital for any future changes at other locations.

Data collection examined spinal fusions at the cervical level, including but not limited to, anterior cervical discectomy and fusion (ACDF), anterior cervical corpectomy and fusion (ACCF), and posterior cervical decompression and fusion (PCDF). This region of surgical manipulation requires heightened surgical team awareness of surrounding nerves and vasculature. While intraoperative neuromonitoring (IONM) is controversial in its ability to increase safety and reduce iatrogenic injury during cervical procedures, it is still frequently used

and increases the requirement of a supplemental remifentanil infusion to provide a still surgical field (Chandra et al., 2022). Furthermore, procedures involving the cervical spine are predicted to increase by 13.3% from 2020 to 2040, emphasizing the need for superior management of analgesia to reduce postoperative complications (Wilson Jr. et al., 2023).

Project Objectives

While remifentanil administration is encouraged in spinal fusion cases for greater intraoperative safety, this practice is affected by drug accessibility, cost, known potential postoperative complications such as opioid-induced hyperalgesia, and provider understanding (Nagelhout & Elisha, 2018). This QI project aimed to analyze current provider practices of multimodal analgesia administration to enhance anesthesia provider practice, improve the hospital's financial gain, and promote patient comfort and health.

A measure of success is identifying whether the choice of specific pain medication administration or use alongside a remifentanil infusion was associated with lower self-reported pain scores in the PACU. Through recognition of changes impacting expenditures and patient experience, this quality improvement project can expand into future evidence-based projects. A second measure of success is the ability to recommend next steps for quality advancement. Analyzing the complexities of remifentanil and optimal pain management strategies benefits the organization, practitioner, and patient.

CHAPTER II: LITERATURE REVIEW

Minimizing pain and its associated side effects is a vital component of anesthesia practice. While remifentanil is an analgesic frequently used for transient, painful stimulation or akinesia, it is associated with a greater risk of postoperative complications (Niedermayer et al., 2020). This QI project sought to examine the current practices of multimodal analgesic administration when using a short-acting remifentanil infusion to identify potential areas of improvement. The primary outcome was self-reported pain scores in the PACU. The secondary outcome was analgesic medication requirements in the postoperative period.

Key Topics

A literature review was conducted using PubMed, CINAHL, and Google Scholar. Keywords for the search included remifentanil, fentanyl, hydromorphone, methadone, opioids, ketamine, dexmedetomidine, lidocaine, magnesium, surgery, spinal surgery, and hyperalgesia. Sources from 2018 to the present were included to compile a comprehensive review of the current literature on remifentanil use in the intraoperative setting, as well as postoperative outcomes. To ensure finding relevance, studies conducted on non-human subjects, children, and pregnant women were excluded, as well as non-English articles. The review aimed to assess the highest level of evidence attainable, prioritizing randomized controlled trials over non-research reports. Scholarly works revealed information on current practices regarding remifentanil use, comparison to other opioids, postoperative hyperalgesia, and multimodal analgesic administration.

Current Practices

From labor analgesia to craniotomies, remifentanil has a variety of uses both in and out of the operating room. Textbooks do not offer a set list of procedures that remifentanil is used for,

but rather recognize its immense applicability (Nagelhout & Elisha, 2018). Several studies have explored its usage and efficacy for various types of surgeries. This section serves to identify the types of procedures most often highlighted in the literature on remifentanil; study findings are then detailed in subsequent sections of the literature review.

A recent study utilized a 14-question survey that was sent to 28 European Low-Grade Glioma Network (ELGGN) centers to identify the anesthetic management practices of awake neurosurgical patients (Arzoine et al., 2020). Twenty centers responded and 55% of these anesthesia teams utilized remifentanil infusions (Arzoine et al., 2020). Other pain management medications included tramadol, morphine, alfentanil, fentanyl, sufentanil, and dexmedetomidine (Arzoine et al., 2020). The most common pain treated was that of vessel manipulation, yet skull clamp pins and positioning were other notable surgical portions of discomfort (Arzoine et al., 2020). Another neurosurgical study looked at patients who underwent spinal canal stenosis or scoliosis surgeries (Shariat Moharari et al., 2021). This double-blinded randomized clinical trial compared fentanyl versus remifentanil infusions in terms of postoperative pain scores and morphine consumption up to two days after discharge from the PACU (Shariat Moharari et al., 2021).

Multiple studies have investigated the use of remifentanil in thyroid procedures, as it is commonly used to minimize coughing and potential disruption of the surgical correction (Jaffe et al., 2019). One notable double-blinded, randomized controlled trial looked at the effect of an abrupt withdrawal versus a gradual discontinuation of a remifentanil infusion during thyroid surgery (Saxena et al., 2019). Similarly, a retrospective study compared postoperative pain and opioid usage among those treated with high-dose and low-dose remifentanil for thyroidectomy (J. X. Wu et al., 2019).

Remifentanil has also been studied in a variety of other procedures, such as total knee arthroplasties (TKA), tracheostomies, cardiac surgeries, bariatric interventions, esophageal procedures, gastric/intestinal surgeries, and gynecologic operations (Chang et al., 2019; Chung et al., 2023; de Hoogd et al., 2019; Mohseni et al., 2023; Niedermayer et al., 2020; Ren et al., 2022; Sung et al., 2023; Wang et al., 2023). A study by de Hoogd et al. (2019) examined 126 patients undergoing cardiothoracic surgery involving a sternotomy. Study participants were randomly selected to either receive a remifentanil infusion or small boluses of fentanyl intraoperatively (de Hoogd et al., 2019). Postoperative thermal and pain thresholds were measured three days and one year later, both with no significant differences (de Hoogd et al., 2019). As such, remifentanil does not appear to cause chronic thoracic pain (de Hoogd et al., 2019). Ren et al. (2022) investigated the effects of intraoperative remifentanil dosing on postoperative pain using a retrospective observational study. Subjects included patients undergoing esophageal, gastric, or intestinal surgery, and a patient-controlled epidural was instituted postoperatively (Ren et al., 2022). The patients were grouped into low-dose and high-dose remifentanil groups; no significant differences were observed in pain scores at postoperative day one (Ren et al., 2022). Sung et al. (2023) also completed a retrospective study comparing the use of remifentanil and sufentanil in robotic gynecological procedures. While the recovery time was similar for both groups, sufentanil was found to have superior pain control as evidenced by a lower pain score as well as fewer analgesics administered in PACU (Sung et al., 2023). A similar study by Wang et al. (2023) compared remifentanil infusions and corresponding chronic postsurgical pain after video-assisted thoracic surgery. This prospective observational study looked at pain scores one year after surgery, demonstrating an infusion rate greater than 0.2 mcg/kg/min was associated with a greater incidence of chronic pain (Wang et al., 2023).

The studies listed above collectively demonstrate that remifentanil is currently used in a variety of surgical procedures. The conclusion of best practice regarding remifentanil administration, however, is to be determined.

Multimodal Analgesia

Multimodal analgesia refers to a pain management technique that draws from several pharmacological classes of analgesics to target receptors at multiple points along the pain pathway. This approach has become more favorable in recent years, with the goal of minimizing narcotic use and promoting a quicker recovery (Nagelhout & Elisha, 2018). While several sources encourage this practice, few studies have evaluated optimal medication administration choice and timing alongside remifentanil use. A retrospective study of 271 patients compared three interventions in laparoscopic bariatric surgeries: A dose of sufentanil followed by a remifentanil infusion, a dose of sufentanil followed by a dexmedetomidine infusion, and a dose of remifentanil followed by multimodal medications, such as dexmedetomidine, magnesium, lidocaine, and methadone (Silva et al., 2022). The group of patients receiving multimodals experienced the lowest postoperative pain scores, largely attributed to the use of methadone (Silva et al., 2022). However, this group also experienced significantly higher rates of hypotensive events, likely due to the use of magnesium and dexmedetomidine (Silva et al., 2022).

The benefit of pairing remifentanil with supplemental analgesics was supported by an observational study regarding pain management in coronary artery bypass grafting (Weinberg et al., 2024). The first group of fast-track cardiac anesthesia patients received remifentanil with methadone, dexmedetomidine, lidocaine, magnesium, ketamine, and/or paracetamol (Weinberg et al., 2024). Meanwhile, the second control group was managed with fentanyl, oxycodone,

and/or morphine (Weinberg et al., 2024). The first group not only had reduced pain scores on postoperative day one, but also received less total intravenous morphine equivalents in the first 48 hours (Weinberg et al., 2024).

While the prior studies focused on a range of multimodal analgesics, the following sections break down the specific analgesics included in this quality improvement project. Narcotics, such as fentanyl, hydromorphone, and methadone, provide profound pain relief, yet possess addictive properties and the potential for severe side effects. Interacting with various receptors with analgesic properties, ketamine, dexmedetomidine, lidocaine, and magnesium are often implemented to reduce the risk for opioid-dependence. Understanding the benefits and risks of these medications is necessary to gain insight on why providers choose to utilize certain drugs for pain control.

Fentanyl

Fentanyl is a frequently administered opioid. With a rapid onset and short duration of action, it can blunt the sympathetic response to direct laryngoscopy and treat transient surgical pain (Nagelhout & Elisha, 2018). While two notable studies compared fentanyl to remifentanil infusions, no studies that looked specifically at the interaction between the two and pain control in the PACU could be located.

One prospective, randomized, double-blinded clinical trial recruited 70 patients undergoing laparoscopic procedures (Asakura et al., 2018). One group received a fentanyl-based anesthetic and the other received a remifentanil infusion (Asakura et al., 2018). Postoperatively, the fentanyl group had a better quality of recovery, although this finding was not statistically significant due to sampling discrepancies (Asakura et al., 2018). Notably, the fentanyl group

experienced better post-surgical physical comfort and more time out of bed (Asakura et al., 2018).

Comparing similar opioids, a randomized, double-blinded clinical trial was conducted on 340 patients undergoing a transvaginal ultrasound guided oocyte retrieval (TUGOR) (Farzi et al., 2019). In this study, patients were either given alfentanil, fentanyl, or remifentanil (Farzi et al., 2019). Postoperative pain scores, patient-reported satisfaction, and hemodynamic variables were all found to be equivocal (Farzi et al., 2019). The only notable outlier was the first ability to follow commands, with the quickest being the remifentanil group and the slowest being the fentanyl group (Farzi et al., 2019).

Largely, the literature is ambiguous on postoperative outcomes for remifentanil and fentanyl. Because both drugs activate the mu-opioid receptor, it is unsurprising that similar results are seen. However, more studies are needed to assess the drug synergism. While this project has made small strides in understanding the complex interplay, this is a robust topic for future research.

Hydromorphone

The ultrashort half-life of remifentanil suggests the need for timely administration of long-acting opioids to bridge the gap in analgesia (de Hoogd et al., 2019). Hydromorphone is an ideal agent for moderate to severe acute postoperative pain (Nagelhout & Elisha, 2018). Not only does it provide 8 times the pain relief of morphine, but it also can be administered in a variety of ways (Nagelhout & Elisha, 2018). Notably, it does cause typical opioid-induced side effects like respiratory depression, nausea, and constipation.

A study analyzing 60 patients undergoing thyroidectomies assessed the use of hydromorphone, parecoxib sodium, and administration of both to minimize the risk of opioid-

induced hyperalgesia (OIH) (Zhou et al., 2022). It was determined that the combination of hydromorphone and parecoxib sodium after remifentanil infusion alleviated OIH and reduced recovery time (Zhou et al., 2022). This study points to hydromorphone as an effective, long-acting analgesic option for the postoperative period.

Methadone

Methadone shows immense post-surgical benefit. It exerts its effect on both the mu-receptor and the N-methyl-D-aspartate (NMDA) receptor, providing analgesia and preventing the reuptake of serotonin and noradrenaline (Silva et al., 2022). Credited to the NMDA receptor antagonist, it is believed to prevent OIH (Weinberg et al., 2024). Potentiation of the "feel good" hormones serotonin and noradrenaline can positively modulate pain (Weinberg et al., 2024). Lastly, methadone has an elimination half-life of up to 36 hours, leading to less narcotics administered in the immediate recovery and post-discharge periods (Silva et al., 2022).

While no studies that addressed interactions between methadone and remifentanil were located, methadone does have a proven role in multimodal analgesia. Alongside similar adjuncts, it consistently produces lower postoperative pain scores (Silva et al., 2022; Weinberg et al., 2024). The effects provided synergistic pain relief with dexmedetomidine, contributing to an opioid-sparing anesthetic (Weinberg et al., 2024). The reduction in opioid consumption directly correlates with reduced postoperative nausea and vomiting (PONV), accelerating the recovery process (Silva et al., 2022).

Ketamine

The combination of ketamine and remifentanil has been extensively researched. Like methadone, ketamine is a NMDA receptor antagonist, inhibiting the hyperalgesic effect commonly associated with remifentanil (Ates et al., 2021). Uniquely, ketamine does not depress

respirations, contributing to adequate ventilatory effort and stable hemodynamics (Efe Mercanoglu et al., 2022). However, this drug is associated with potent hallucinogenic effects, particularly in vulnerable populations like the elderly and veterans (L. Zhao et al., 2024).

Although the studies included in this literature review resulted in varied findings, all concluded a benefit in administering ketamine with remifentanil. Three of the studies demonstrated lower postoperative pain scores (Ates et al., 2021; Efe Mercanolgu et al., 2022; Qi et al., 2024). One randomized, prospective study found that adding 10 mcg/kg/min of ketamine to the remifentanil infusion led to lower postoperative pain scores and IV-PCA morphine consumption in the first 48 hours (Efe Mercanoglu et al., 2022). A similar prospective, double-blinded controlled study looked at 420 patients that underwent a video-assisted thoracoscopic lobectomy (VATs) (Qi et al., 2024). Half received a ketamine bolus of 0.5 mg/kg, followed by an infusion of 0.25 mg/kg/h. Remifentanil and propofol infusions were also utilized (Qi et al., 2024). Pain scores, measured by the visual analogue scale (VAS), were lower on postoperative day 1 and 3 (Qi et al., 2024). In the third prospective, randomized, double-blind study, the results of a ketamine bolus followed by a low-dose infusion (in combination with remifentanil) during septorhinoplasty were analyzed (Ates et al., 2021). Pain scores, also measured by VAS, were lower in the ketamine group at 1 hour, 2 hours, 4, hours, 8 hours, 12 hours, and 24 hours (Ates et al., 2021).

This study also noted that none of the 24 patients in the ketamine group required a rescue opioid postoperative. Conversely, six patients in the control group required additional narcotics (Ates et al., 2021). A study by Kasputytė et al. (2020) monitored patients undergoing bariatric surgery. In this prospective, randomized, double-blinded trial, patients either received 0.15 mg/kg of ketamine or saline before surgical incision. Both groups received a remifentanil

infusion (Kasputytė et al., 2020). Although the postoperative pain scores were statistically similar, the ketamine group required less morphine in PACU (Kasputytė et al., 2020). Unfortunately, this study was only composed of 32 patients, a smaller sample size. Regardless, findings indicate potential positive outcomes with the use of ketamine with remifentanil (Kasputytė et al., 2020).

Three studies determined that ketamine lowered intraoperative remifentanil requirements (Fujii & Nishiwaki, 2022; Qi et al., 2024; L. Zhao et al., 2024). Qi et al. (2024) studied the aforementioned lobectomy patients and found that the total dose of remifentanil required went from 2358.2±548.1 mcg to 1414.8±296.3 mcg when ketamine was added. Fujii and Nishiwaki (2022) looked at remifentanil and ketamine in extensive head and neck procedures. They found a statistically significant difference as well: the remifentanil dose decreased to 0.15±0.05 mcg/kg/min with ketamine compared to 0.17±0.05 mcg/kg/min without ketamine (Fujii & Nishiwaki, 2022). Lastly, ketamine use in 90 laparoscopic cholecystectomy patients was examined in a prospective, randomized controlled trial (L. Zhao et al., 2024). The patients either received normal saline as a control, low dose ketamine, or high dose ketamine (L. Zhao et al., 2024). Both the low dose and high dose ketamine groups required less propofol, remifentanil, and sufentanil intraoperatively (L. Zhao et al., 2024). This was linked to a quicker recovery period (L. Zhao et al., 2024).

Finally, despite the potential for adverse sympathomimetic side effects, ketamine's stimulating properties were not encountered in any of the prior studies. In the septorhinoplasty trial, no psychotomimetic effects were experienced, associated with the smaller dose as well as premedication with midazolam (Ates et al., 2021). Efe Mercanoglu et al. (2022) did not report common side effects like sleepiness or drowsiness. Additionally, none of the bariatric patients

experienced agitation or hallucinations, and all reported satisfactory pain management (Kasputytė et al., 2020). L. Zhao et al. (2024), however, did find that 3.33% of the high dose ketamine group had significant oral secretions, nightmares, and diplopia. Overall, ketamine has been associated with few adverse reactions and plays a key role in multimodal pain management.

Dexmedetomidine

Dexmedetomidine is an emerging adjunct in the anesthesia field. It is synergistic with opioids, blocking descending pain pathways and attenuating the surgical stress response (Zheng et al., 2024). Dexmedetomidine is predominantly utilized as an anxiolytic in the intensive care unit, available as both a bolus and an infusion. Although it is frequently associated with less postoperative pain, it can contribute to significant hypotension and bradycardia (Zheng et al., 2024).

Multiple studies concluded that patients experienced less pain and lower postoperative analgesic requirements. One trial found that the dexmedetomidine group had a longer time until first pain medication administration, lower pain scores in the first 48 hours, and less IV-PCA morphine utilization (Efe Mercanoglu et al., 2022). Although ketamine did show greater promise in reducing narcotic use, dexmedetomidine is a suitable alternative for vulnerable populations (Efe Mercanoglu et al., 2022). A prospective, double-blinded, randomized controlled trial by Zheng et al. (2024) supported these findings. 100 patients undergoing laparoscopic cholecystectomies were given either saline as a control or 0.5 mcg/kg of dexmedetomidine prior to induction, then maintained with propofol and remifentanil infusions (Zheng et al., 2024). Not only did the comparison group have improved pain scores, but they also met extubation criteria faster (Zheng et al., 2024).

Two other studies indicated greater surgical satisfaction. Jia et al. (2020) carried out a prospective trial using three different doses of dexmedetomidine along with a remifentanil infusion. Possessing sedative and hypnotic effects, this alpha 2 agonist mimics natural sleep and allows the patient to reposition themselves during the procedure (Jia et al., 2020). While all 3 groups were able to be awakened and similar numbers were able to move, the lowest-dose dexmedetomidine group had more body movements interfering with the procedure (Jia et al., 2020). Potočnik et al. (2021) looked at the use of intranasal dexmedetomidine and intravenous remifentanil with 40 patients undergoing vitreoretinal procedures. Not only were surgeons more satisfied with the drug combination, but so were patients and anesthesiologists (Potočnik et al., 2021). This was likely because the additional dexmedetomidine lowered remifentanil requirements (Potočnik et al., 2021).

Because remifentanil is associated with respiratory depression, nystagmus, hypotension, and bradycardia, it is frequently compared to dexmedetomidine as an alternative or supplement (Potočnik et al., 2021). Another study by Q. Yang et al. (2023) looked at three different doses of remifentanil with the addition of dexmedetomidine for peritoneal dialysis access placement. Although no significant differences in pain scores were observed for the 3 remifentanil doses, it was found that the low dose group (0.2-0.7 mcg/kg/min) had satisfactory analgesia with the fewest complications (Q. Yang et al., 2023). Similarly, the study by Zheng et al. (2024) found that remifentanil consumption was significantly lower with the addition of dexmedetomidine. While the control group required 624.6±150.6 mcg, the comparison group needed only 569.6±113.9 mcg (Zheng et al., 2024).

A randomized, double-blinded trial looked at the addition of dexmedetomidine to propofol-remifentanil anesthesia in nasal procedures (H. Y. Kim et al., 2021). A bolus of 0.5

mcg/kg lowered half maximal effective concentration of remifentanil by 19% (H. Y. Kim et al., 2021). The addition of dexmedetomidine reduced the incidence of emergence cough, decreased the time to eye opening and extubation, and prevented hypoventilation (H. Y. Kim et al., 2021). However, it was associated with a greater incidence of PONV (H. Y. Kim et al., 2021).

In the colonoscopy trial, all 3 dexmedetomidine groups had lower systolic blood pressures, heart rates, and respiratory rates (Jia et al., 2020). Additionally, while no hypotension resulted, the high dose dexmedetomidine group had notable bradycardia (Jia et al., 2020). However, patients in the vitreoretinal surgery study did experience lower mean arterial pressures (MAPs) with the addition of dexmedetomidine (Potočnik et al., 2021). There were no complications when compared with the remifentanil-only group (Potočnik et al., 2021). Lastly, the laparoscopic cholecystectomy study showed a reduction in nausea, vomiting, and cough. It also demonstrated a lower MAP and HR (Potočnik et al., 2021). While dexmedetomidine has significant hemodynamic effects that may preclude its use, it can provide analgesia and anxiolysis in the right patient population.

Lidocaine

Lidocaine exerts its effect on sodium channels, blocking the transmission of pain signals (Nakhli et al., 2018). It has anti-inflammatory properties, prevents hyperalgesia, and has the potential to reduce PONV and hospital LOS (Nakhil et al., 2018). It also works synergistically with opioids, possibly decreasing drug administration and enhancing cost savings (Nakhil et al., 2018).

Nakhil et al. (2018) conducted a randomized, double-blinded trial on 60 non-laparoscopic renal surgery patients. Both the systemic lidocaine infusion group and the normal saline control group were maintained with the volatile agent isoflurane and remifentanil (Nakhil et al., 2018).

Like other multimodal analgesics, lidocaine lowered the required remifentanil dose by 27% and improved time from anesthetic emergence until endotracheal extubation (Nakhil et al., 2018).

Another study conducted by Peng et al. (2021) concluded that the addition of lidocaine lowered the remifentanil dose by 13%. Researchers primarily focused on the short-term pain scores after a hysteroscopy with lidocaine and remifentanil use (Peng et al., 2021). Measured by the VAS, pain scores were lower at 30 minutes and 4 hours postoperatively (Peng et al., 2021). Additionally, the incidence of a sore throat nearly halved, from 47.5% to 22.5%, and self-reported PONV was also reduced (Peng et al., 2021).

K. Zhao et al. (2022) primarily focused on postoperative quality of recovery (QoR) with the addition of lidocaine to a propofol-remifentanil anesthetic. 60 patients underwent a supratentorial tumor resection, with half receiving a lidocaine infusion and half receiving a normal saline control infusion. QoR scores were measured on both postoperative day (POD) 1 and 2 (K. Zhao et al., 2022). The lidocaine patients reported feeling physically and emotionally better, with lab levels demonstrating less pro-inflammatory mediators (K. Zhao et al., 2022). These findings support neuroprotective properties and enhanced cognitive recovery post-surgery (K. Zhao et al., 2022). While lidocaine must be dosed and titrated carefully, it may aid with a quicker recovery and lower surgical costs.

Magnesium

A naturally occurring element, magnesium sulfate has both antihypertensive and analgesic qualities. It can safely decrease systemic vascular resistance (SVR) while attenuating the surgical stress response, correlating with postoperative pain relief (Tan et al., 2019). As an NMDA receptor antagonist, it plays an important role in blocking excitatory amino acids linked

to cerebral damage (Y. H. Su et al., 2023). Through this neuroprotective effect, magnesium sulfate has the potential to reduce cognitive decline in the PACU (Y. H. Su et al., 2023).

A double-blinded, randomized, controlled clinical trial monitored the hemodynamic changes in 69 patients undergoing a laparoscopic partial gastrectomy (Tan et al., 2019). One group received a bolus and infusion of magnesium sulfate and the other group received a saline control infusion. All patients received a remifentanil infusion (Tan et al., 2019). The intervention group reported lower pain scores at both 5 and 20 minutes postoperatively, and the intraoperative remifentanil dose was lower (Tan et al., 2019). Magnesium sulfate was also associated with a significant reduction in MAP, SVR, and central venous pressure (CVP) (Tan et al., 2019).

Y. H. Su et al. (2023) measured the incidence of emergence delirium in two cohorts receiving a remifentanil infusion. Of 70 patients undergoing radical mastectomies, half also received a magnesium sulfate infusion. The magnesium sulfate group had less agitation, postoperative pain, and overall remifentanil dose (Y. H. Su et al., 2023). PONV, time until extubation, and the dose of rescue narcotics needed were similar (Y. H. Su et al., 2023). In conclusion, magnesium sulfate is a safe option to improve pain scores, provide neuroprotection, and lower blood pressure.

Opioid Comparison

Opioids in anesthesia and the perioperative period serve as primary agents for pain management. Several agents with varying clinical applications, comparative efficacy, and pharmacologic profiles are utilized in practice. Commonly utilized opioids include morphine and phenylpiperidine derivatives, such as fentanyl, sufentanil, and remifentanil (S. Yang et al., 2021). Remifentanil is a fast-acting opioid analgesic, favored for its quick onset and offset and lack of accumulation (de Hoogd et al., 2019). Existing research examining opioid use in critically ill

patients showed that remifentanil decreased mechanical ventilation time, ventilation weaning period, and LOS in the intensive care unit (ICU) without significant differences in overall hospital LOS, side effects, and mortality when compared to other opioids (S. Yang et al., 2021). This does account for the adverse effects of opioid administration, such as nausea and/or vomiting or respiratory depression that impacted ICU LOS and mechanical ventilation duration (S. Yang et al., 2021). However, remifentanil is associated with postoperative hyperalgesia (de Hoogd et al., 2019). Additionally, remifentanil was associated with greater costs in anesthesia, but without increased cost of overall hospitalization when compared to other opioids (S. Yang et al., 2021)

Intraoperatively, studies examining the use of remifentanil compared to fentanyl suggested an increase in postoperative pain scores and higher postoperative opioid consumption in the short term in the remifentanil group (Shariat Moharari et al., 2021; de Hoogd et al., 2019). In a study examining 60 surgical spinal cases, the control group receiving 0.07-0.1 ug/kg/h of fentanyl saw a reduction in pain scores and postoperative morphine consumption during the first 12 hours after surgery compared to the remifentanil group receiving 0.1-0.2 ug/kg/min intraoperatively (Shariat Moharari et al., 2021). Another study of 126 cardiothoracic patients randomized to receive a continuous remifentanil infusion versus intermittent fentanyl administration showed that the remifentanil group received more opioids in the first 48 hours postoperative compared to the fentanyl group and reported greater thoracic pain three months after surgery (de Hoogd et al., 2019). There were no reports of heightened or abnormal pain response one year after surgery in either group (de Hoogd et al., 2019). Growing evidence points towards opioid induced hyperalgesia being associated with remifentanil.

Varying strategies of narcotic administration are practiced according to individual patient needs, such as implementing a continuous opioid infusion, delivering intermittent boluses, or a combination technique. The literature highlights that remifentanil has favorable qualities in intraoperative analgesia; however, its potential to induce opioid-induced hyperalgesia and reports of post-operative pain pose challenges in anesthesia practice.

Opioid-Induced Hyperalgesia

Opioid-induced hyperalgesia (OIH) is an adverse effect of opioid administration, frequently associated with remifentanil due its unique, rapid offset. Categorized as a primary or secondary hyperalgesia, highly sensitized signaling pathways produce generalized pain that can be difficult to treat (Santonocito et al., 2018). While the mechanism is not entirely understood, hyperalgesia is also associated with allodynia, resulting in a heightened pain response (Santonocito et al., 2018). Wilson et al. (2021) described mechanisms theorized to contribute to OIH, including alterations in descending pain modulation, N-methyl-D-aspartate (NMDA) receptor activation, increased prostaglandin release, and altered neurotransmitter reuptake. X. Su et al. (2020) linked continuous remifentanil stimulation of G-inhibitory proteins to receptor reduction and promotion of N2RB spinal cord subunit expression, resulting in opioid tolerance. Numerous anesthetic approaches can be taken to minimize the risk of OIH and tolerance, given the growing pandemic of opioid abuse and associated costs.

Remifentanil is desirable in procedures requiring rapid emergence or a TIVA. Currently, no drug substitutions mimic remifentanil's analgesia and metabolic profile without similar adverse effects (Flood et al., 2015). X. Su et al. (2020) investigated the supplementation of propofol to attenuate the incidence of hyperalgesia, concluding that propofol-remifentanil anesthesia was superior in mitigating postoperative hyperalgesia compared to sevoflurane-

remifentanil anesthesia. Z. Wu et al. (2020) proposed dexmedetomidine boluses in thyroidectomy patients receiving remifentanil infusions to reduce postoperative opioid tolerance, noting decreased hyperalgesia at skin incision. Furthermore, Kawanaka et al. (2022) found an association between remifentanil and OIH when the remifentanil infusion was discontinued abruptly, versus slowly weaned until discontinuation, and higher infusion doses. Conversely, the supplementation of a longer-acting analgesic to minimize total remifentanil administration and the addition of a long-acting opioid before the discontinuation of the remifentanil infusion demonstrated a reduced incidence of OIH (Kawanaka et al., 2022). A double-blind randomized controlled trial conducted by D. Kim et al. (2018) noted that remifentanil infusions during gastrectomy procedures correlated with greater postoperative fentanyl use, while doses higher than typical standard dosing produced acute opioid tolerance.

Higher pain levels directly correlate with increased LOS, increased postoperative pain medication usage, and decreased patient satisfaction (Santonocito et al., 2018). These outcomes result in higher costs and admission times beyond the projected LOS. A study conducted by Wang et al. (2023) assessed chronic pain after video-assisted thoracic procedures with three different mean doses of a remifentanil infusion and found 8-10% of the patients experienced significant reduction in quality of life due to chronic pain with low dose remifentanil. While numerous factors contribute to the postsurgical experience, chronic pain affects over 100 million adults in the United States and plays a key role in surging healthcare costs, often contributing to long-term disability (Pitcher et al., 2019). Cohen et al. (2019) noted that the management of chronic pain and opioid tolerance can be time consuming, require multiple visits and therapy adjustments, and result in patient frustration and a reduction in quality of life. These findings

demonstrate the importance of examining post-operative pain levels when remifentanil is utilized.

Spinal Fusion

Spinal procedures pose a high risk of nerve injury, necessitating use of neuromonitoring. Inhaled volatile agents at high doses eliminate the ability of a nerve to respond to stimulation, and a TIVA is often employed to achieve deep sedation without nerve monitor interference (Jaffe et al., 2019). Remifentanil, with its favorable pharmacokinetics, is ideal for this. Two studies investigating its efficacy in pain management in spinal procedures were located. One looked at 60 healthy patients between the ages of 18 and 60 years old who came in for either spinal canal stenosis or scoliosis surgeries (Shariat Moharari et al., 2021). The control patients were treated with fentanyl at a rate of 0.07-0.1 mcg/kg/h, the intervention patients were given a remifentanil infusion at 0.1-0.2 mcg/kg/h, and all patients were given 15 mg/kg of intravenous tylenol 20 minutes before surgical closure (Shariat Moharari et al., 2021). The notable outcomes measured included postoperative pain scores, postoperative opioid use, and the presence of PONV (Shariat Moharari et al., 2021). The results showed the intervention group (remifentanil) required more intravenous morphine administration and had higher associated pain scores in the first twelve hours after surgery (Shariat Moharari et al., 2021). There was no significant difference in PONV between the two groups (Shariat Moharari et al., 2021). Because propofol was co-administered with the remifentanil infusion, it may have mitigated the development of opioid induced hyperalgesia (Shariat Moharari et al., 2021). Thus, the findings of this study show that the remifentanil group required more opioids postoperatively (Shariat Moharari et al., 2021).

The second study was a prospective, randomized, double-blind design with less relevance to this quality improvement project. It found that application of perioperative transcutaneous

electrical acupoint stimulation (pTEAS) led to decreased intraoperative dosing of remifentanil, a decreased heart rate, and less blood loss (X. Wu et al., 2022). This was also associated with improved postoperative outcomes, including a reduction in pain scores, PONV, and dizziness measured from day one to day five postoperatively (X. Wu et al., 2022). It is unclear if the pTEAS or the decreased dosage of remifentanil is associated with the improved outcomes.

Conceptual/Theoretical Framework

The guiding framework for the project was the Plan-Do-Study-Act (PDSA) model. This four-step process is a cyclical method employed to initiate and sustain a change (Agency for Healthcare Research and Quality, 2020). In the "planning" stage, a problem at the project site was identified. The problem was determined to be unclear remifentanil practices with multimodal use and the potential for findings to improve quality of anesthesia provider care. After a literature review was conducted, a method for completing chart reviews was established. Next, in the "doing" stage, data on provider usage of multimodal analgesics and remifentanil, along with associated patient outcomes, were extracted from patient charts. Extracted chart data were then analyzed for cervical spinal fusions in the "studying" phase. Finally, the project concludes with the "acting" phase, providing recommendations for subsequent QI projects. The data collected were used to identify current provider practices, as well as identify potential areas of future study. Projects that utilize the PDSA model provide a basis for further analysis of optimal patient care.

Conclusion

In summary, remifentanil is useful for perioperative pain management and supplemental immobility. It provides unique benefits unlike other opioids, such as potent analgesia, rapid metabolism, and swift emergence from anesthesia. The literature review highlights the various

benefits of remifentanil with multimodal analgesia. However, the review also noted the short-acting narcotic's link to serious adverse effects, such OIH and increased pain medication requirements. Utilizing the PDSA cycle, this QI project sought to examine provider practices and patient outcomes for remifentanil-based anesthesia during spinal fusions. This surgical population frequently requires a remifentanil infusion to maintain stable hemodynamic parameters, minimize agitation upon emergence, and allow for rapid neurological testing. While none of the studies solely investigated remifentanil along with every analgesia adjunct assessed in this project, the review emphasized the importance of multimodal pain relief to reduce opioid consumption and provide a positive patient experience.

CHAPTER III: METHODS

Project Design

Conducted as a retrospective chart review (RCR), this QI project examined current multimodal analgesic practices in cervical spinal surgeries utilizing remifentanil to identify associations between pain scores and pain medication usage postoperatively. This QI project was defined as a retrospective, non-experimental, cohort study, using quantitative data to identify project findings. Institutional Review Board (IRB) approval was received from the project site (medical center). The University's IRB determined this project to be Non-Human Subjects Research. All data collection was carried out in accordance with the guidelines established by both IRBs.

Sample

The larger project population consisted of adult patients, aged 18 years and older who underwent cervical, thoracic, or lumbar spinal fusions utilizing a remifentanil infusion at the project site. These surgical procedures were selected based on clinical relevance and likelihood of remifentanil administration intraoperatively. The sample was obtained from electronic health records (EHRs) with surgical documentation that met inclusion criteria from January 2023 to June 2024. In this specific project, 50 patients who underwent cervical spinal fusions were selected for the RCR.

Inclusion criteria were patients aged 18 years or older who underwent cervical spinal fusion at the project site between January 2023 to June 2024, received a remifentanil infusion intraoperatively, and recovered in the PACU postoperatively. Additionally, the NRS pain score must have been documented in the EHR (described in the following section). Parturients, children, or patients who were directly transferred from the OR to an intensive care unit were

excluded from the project. The exclusion criteria were selected to minimize the risk of confounding factors due to the distinct physiological considerations, leading to an increased variability of outcomes. Additionally, patients who had combined and multi-region spinal fusion procedures were included for comprehensive analysis.

Setting

The project took place at an urban hospital in the southeast United States. This level one academic medical center operates as a tertiary care center equipped with 53 operating rooms. More than 16,000 surgeries are performed annually to serve a diverse patient population with varying surgical needs. At this facility, remifentanil is utilized frequently in neurosurgical procedures. This institution was chosen for the project based on advanced clinical infrastructure, high case volume, accessible EHR system, and collaborative perioperative staff. Patient management includes input and care from nurses, MDAs, CRNAs, surgical technicians, and surgeons, requiring excellent communication between the teams to optimize patient outcomes. These qualities created a conducive environment for examining the correlation between analgesic management and patient outcomes. Patient data and monitoring, as well as care coordination, are integrated into the workflow via the Epic EHR.

Data Collection

See Appendix A for the Data Collection Plan. Demographic data that were extracted from the EHR to describe the sample included: age (18 years and older), gender (charted as male or female), and race/ethnicity. Additional descriptive information that was collected was ASA status. This is a measure that is scored I-VI and indicates surgical risk due to significant comorbidities, with I=lowest risk and VI=highest risk (American Society of Anesthesiologists, 2020). Data collected to examine intraoperative care included:

- Documented use of remifentanil infusion
- Documentation of remifentanil infusion initiation and discontinuation times and total dose
- Documentation of any fentanyl, hydromorphone, ketamine, dexmedetomidine, methadone, lidocaine infusion, magnesium infusion administration, including timing, discontinuation, and total dose
- Anesthesia start and stop times
- Documentation of pain score in PACU (NRS)
- Documentation of postoperative pain medication administration (type, dose, time, route)
- Time of PACU admission and discharge (or documented handoff to floor nurse)

Measurement Tools

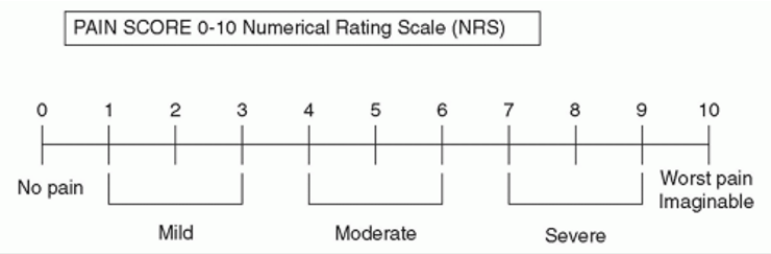
This project utilized PACU Chart Review guidelines, found on the facility's SharePoint Site, to determine the appropriate charting of pain scores, pain medication administration, and handoff/discharge (Appendix B). According to this documentation, all the data that was collected as part of the PACU chart review is standard practice at this level one academic medical center. Pain assessments are to be collected upon PACU admission, every half hour while in Phase I PACU, and every hour while in Phase II PACU. Pain scores are charted prior to pain medications and must be followed by another pain score within 20 minutes following administration. In terms of handoff, Phase I CRNA to nurse handoff, Phase II nurse handoff, and discharge documentation must all be completed with accurate times noted.

Currently, the NRS is considered the most reliable measure of adult pain level (Safikhani et al., 2018). Depicted in Figure 1, patients are asked to describe pain levels from zero, or no pain, to ten, or the worst imaginable pain. Nurses must document this pain score upon admission

to the PACU, every thirty minutes in Phase I of PACU, every hour in Phase II of PACU, and reassess twenty minutes after an intervention. Relevant pain scores during the PACU stay were collected.

Figure 1

Numerical Rating Scale (NRS)



Note. From " The McGill Pain Questionnaire: Major properties and scoring methods," by Melzack, R., 1975, *Pain*, *1*(3), p.277-299.

The secondary outcome of interest was analgesic medication requirements in the postoperative period. The data that was collected from the EHR included documentation of postoperative pain medication administration to include the type, dose, time, and route. Analgesic administration data was pulled directly from the Medication Administration Record (MAR). Common PACU order sets include pain medications such as hydromorphone, fentanyl, hydrocodone-acetaminophen, and methocarbamol. Time of administration and doses were collected for pain medications administered in PACU.

Data Collection Procedures

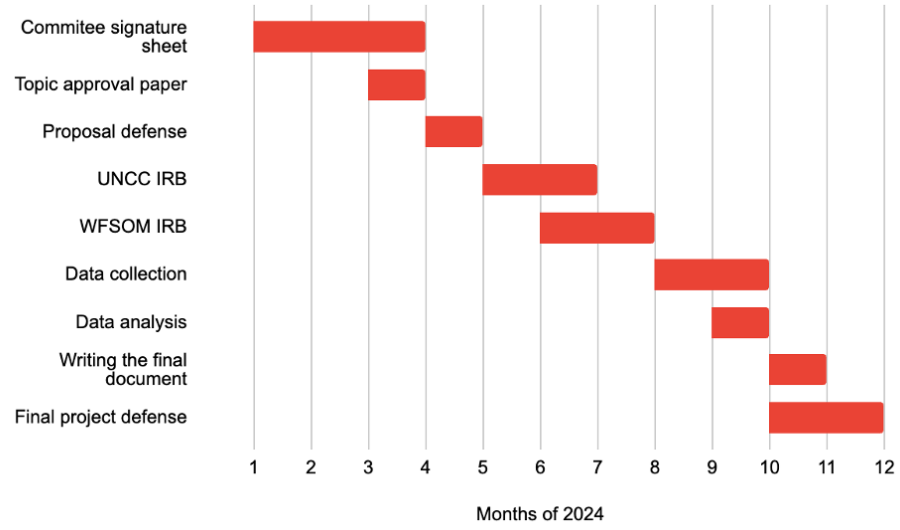
An RCR was conducted to analyze multimodal analgesia practices in cervical spinal fusions utilizing remifentanil. The goal of the review process was to gather detailed information regarding the patients sampled, the administration of remifentanil and adjunct analgesics, postoperative pain scores, and postoperative analgesic administration in the PACU. The data

collection process included identifying patient charts, collecting data from the EHR, and documenting the information in a standardized data collection tool (Appendix C).

The chart review process occurred in August 2024, as depicted by the timeline in Figure 2. The most recent 50 patients who met the inclusion criteria (within the time frame of January 2023 to June 2024) were selected for review for each surgical procedure. During data collection, the surgical visit record in the EHR was reviewed, and the data was collected as indicated in Appendix A. The data was then imported to REDCap (Research Electronic Data Capture), a secure platform for storing and organizing data during the chart review process. REDCap training was completed to ensure proficiency in data management. After extracting patient charts from the EHR, relevant data was entered into REDCap as depicted in Appendix C. This tool allowed secure data entry ensuring accuracy and consistency, reducing the risk of errors or a breach of confidentiality.

Figure 2

Timeline



Note. Depicted was the timeline for successful project completion.

Data Analysis

Data were manually collected from patient charts within the Epic EHR. Relevant charts were identified using Epic's Slicer Dicer tool, allowing efficient filtering of relevant charts that met the inclusion criteria listed in Appendix A. Access to individual patient charts was both password protected and restricted to the project team only. Once the data was extracted, it was securely transferred to REDCap.

Findings for each spinal fusion level were divided between the three subtypes in the larger QI project. Descriptive analysis was utilized to calculate the means, standard deviations, and frequencies for the different multimodal analgesics administered and patient demographics. The strength of correlations were assessed with *p* levels, followed by further exploration of the clinical relevance of the findings. Linear regression analysis, listed as $b = xx$, $t = xx$, $p = xx$, determined if the different analgesia medications alongside a remifentanil infusion had statistically significant associations with postoperative pain scores and pain medication administration. Finally, the strength and significance of the correlations were assessed using Pearson's r correlation, listed as $r = xx$, $p = xx$. Findings were considered statistically significant if $p < .05$.

Ethical Considerations

Several ethical protections were instituted to ensure protection of sample data. Patients were de-identified when entering information into the data collection tool. They were assigned a number from 1 to 50 for each surgical type. To protect confidentiality, no names, birthdates, addresses, or other identifying information was removed from the EHR or recorded on the data collection tool. All the information gathered was stored in REDCap, securely protected by the hospital's password-protected firewall. To ensure this system of data management is sound and

ethical, IRB approval was obtained from the project site (Appendix E). The University declared the project Non-Human Subjects Research (Appendix D).

CHAPTER IV: PROJECT FINDINGS/RESULTS

Sample Characteristics

The chart review for cervical spinal fusions included 50 individuals, out of a potential 84 charts meeting search parameters. The 50 patients who most recently underwent surgery were selected for inclusion. The inclusion criteria were as follows: cervical spinal fusion performed at the level one academic medical center between January 2023 and June 2024, patient age of at least 18 years, and utilized a remifentanil infusion. The exclusion criteria, also detailed in Appendix A, were as follows: pregnant or parturient patients, minors (under the age of 18), and post-surgical admission to the intensive care unit (ICU).

The sample consisted of 24 women and 26 men, with an average age of 63.70 years (*SD* = 11.83). There was limited racial variability, with 35 white, 14 black, and 1 listed as “other” in the EHR. The mean ASA score was 2.86 (*SD* = 0.40), with a median of 3 and a range of 2 to 4.

Cervical Surgery Findings

The remifentanil infusion run time averaged 230 minutes (*SD* = 113.27), with a median of 208.50 minutes. The average total dose of remifentanil given was 3.55 mg (*SD* = 2.02), with a median of 2.98 mg.

The findings depicted in Table 1 show the intraoperative adjuncts used to combat opioid-induced hyperalgesia. 96% of patients got intraoperative fentanyl. About half the patients got hydromorphone and ketamine. A quarter of patients got dexmedetomidine. 12% of patients got magnesium; 10% of patients got other intraoperative adjuncts; 8% of patients got methadone. No patient got a lidocaine infusion.

Table 1

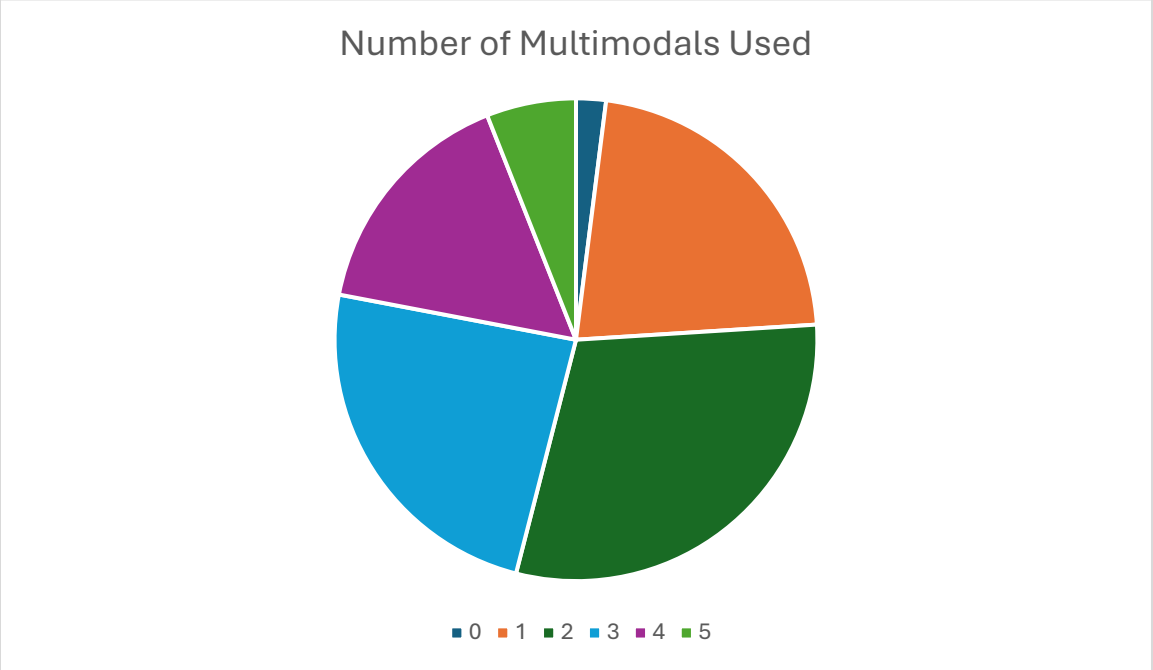
Proportion of Multimodals Administered Intraoperatively for Cervical Cases

Intraoperative multimodals	Proportion
Fentanyl	0.96
Hydromorphone	0.52
Methadone	0.08
Ketamine	0.46
Dexmedetomidine	0.24
Lidocaine	0.00
Magnesium	0.12
Other	0.10

The number of multimodals given intraoperatively ranged from 0 to 5, $M = 2.48$ ($SD = 1.23$), Median = 2. Figure 3 illustrates the breakdown of the number of multimodals used. The most frequently used intraoperative adjunct was fentanyl.

Figure 3

Multimodal Breakdown for Cervical Cases



Note. The most common number of multimodals used was 2, followed by 3, 1, 4, 5, and 0.

The findings depicted in Table 2 show the pain medications that were administered in PACU. 84% of patients got hydromorphone. 30% of patients got methocarbamol. 8% or less got postoperative fentanyl, acetaminophen, oxycodone, or oxycodone-acetaminophen. No patients got ibuprofen, toradol, or hydrocodone-acetaminophen.

Table 2

Proportion of Pain Medications Given in PACU for Cervical Cases

Pain medications given in PACU	Proportion
Hydromorphone	0.84
Fentanyl	0.08
Acetaminophen	0.08
Ibuprofen	0.00
Toradol	0.00
Methocarbamol	0.30
Hydrocodone-Acetaminophen	0.00
Oxycodone-Acetaminophen	0.02
Oxycodone	0.06
Other	0.00

In PACU, patients received between 0 and 11 doses of pain medication. The average was 2.84 doses (*SD* = 2.30), and the median was 2.5 doses. In PACU, the vast majority of patients got hydromorphone, with the second most common agent being methocarbamol. Looking at the most common agents administered in PACU, the total dose of fentanyl in PACU ranged from 75 mcg to 200 mcg. The dose had a mean of 118.75 mcg (*SD* = 55.43) and a median of 100 mcg. The total dose of methocarbamol in PACU ranged from 500 mg to 1000 mg. The dose had a mean of 866.67 mg (*SD* = 185.81) and a median of 1000 mg. The total dose of hydromorphone in PACU ranged from 0.25 mg to 5.0 mg. The dose had a mean of 1.49 mg (*SD* = 0.85) and a median of 1.5 mg. The average NRS score in PACU ranged from 0 to 9, with a mean of 4.41 (*SD* = 2.17) and a median of 4.67.

Linear regression determined there was no statistically significant association between the number of multimodals and the average NRS scores in PACU ($b = 0.32$, $t = 1.28$, $p = 0.207$). The association of the number of multimodals with the number of doses of pain medications in PACU was not statistically significant ($b = 0.27$, $t = 1.00$, $p = 0.322$). There were no statistically significant associations between the number of multimodals and the PACU fentanyl dose ($b = -21.30$, $t = -0.99$, $p = 0.424$), the PACU hydromorphone dose (b = 0.08, $t = 0.79$, $p = 0.433$), or the PACU methocarbamol dose ($b = 6.25$, $t = 0.12$, $p = 0.908$).

None of the individual intraoperative multimodals (fentanyl, hydromorphone, methadone, ketamine, dexmedetomidine, lidocaine, magnesium, other) had a statistically significant association with pain medication administration or NRS scores in PACU. The Pearson correlation r ranged from -0.12 to 0.24; p ranged from 0.10 to 0.99.

Larger QI Project Sample Characteristics

The larger QI project consisted of cervical, thoracic, and lumbar spinal fusions with the same inclusion and exclusion criteria previously mentioned. Out of the 150 individuals sampled, there were 87 women and 63 men. The average age was 62.19 years old ($SD = 14.41$). There were 122 white, 20 black, 3 Hispanic, 2 Asian, and 3 other individuals. The ASA score had a mean of 2.77 ($SD = 0.45$), median of 3, and range between 2 and 4. Overall, the larger statistics were very similar to the cervical findings.

Larger QI Project Findings

When considering the larger QI project, the remifentanil infusion run time averaged 296.69 minutes ($SD = 112.06$), with a median of 287 minutes. This is considerably longer than the cervical cases only. The average total dose of remifentanil given was 4.44 mg ($SD = 2.13$), with a median of 4.11 mg, consistent with the longer case time.

The intraoperative adjuncts for all 150 cases are seen in Table 3. 96% of patients got intraoperative fentanyl. 67% of the patients got hydromorphone. A little more than half got ketamine. A quarter of patients got dexmedetomidine and other adjuncts. 15% of patients got methadone; 10% of patients got magnesium. There were no lidocaine infusions given. Overall, there were more multimodals used the larger QI project than for the cervical cases alone.

Table 3

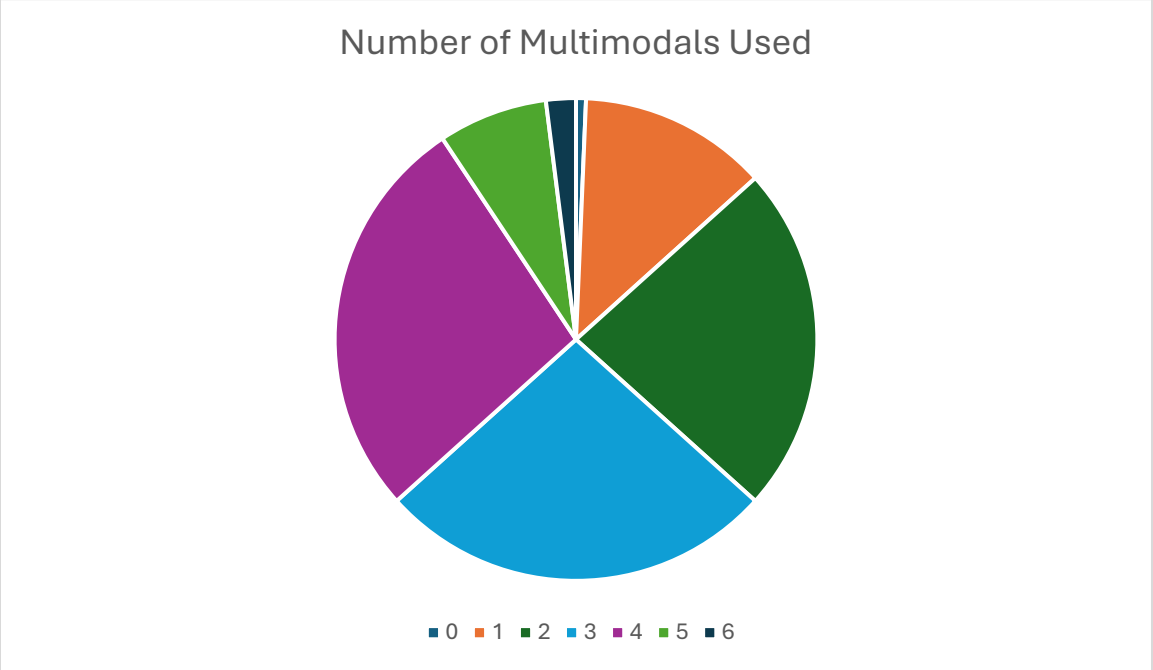
Proportion of Multimodals Administered Intraoperatively for Cervical, Thoracic, and Lumbar Cases

Intraoperative multimodals	Proportion
Fentanyl	0.96
Hydromorphone	0.67
Methadone	0.15
Ketamine	0.55
Dexmedetomidine	0.26
Lidocaine	0.00
Magnesium	0.10
Other	0.25

The number of multimodals given intraoperatively ranged from 0 to 6, $M = 2.95$ ($SD = 1.22$), Median = 3. Figure 4 illustrates the breakdown of the number of multimodals used. Again, the most frequently used intraoperative adjunct was fentanyl. In PACU, most patients got also hydromorphone, with the second most common agent being methocarbamol.

Figure 4

Multimodal Breakdown for Cervical, Thoracic, and Lumbar Cases



Note. The most common number of multimodals used was 4, followed by 3, 2, 1, 5, 6, and 0.

The pain medications given in PACU for all 150 cases are seen in Table 4. 83% of patients got hydromorphone. 27% of patients got methocarbamol. 14% got postoperative fentanyl. 5% or less got acetaminophen, oxycodone, oxycodone-acetaminophen, hydrocodone-acetaminophen, or other. No patients got ibuprofen or toradol. This is very consistent with the cervical procedure results.

Table 4

Proportion of Pain Medications Given in PACU for Cervical, Thoracic, and Lumbar Cases

Pain meds given in PACU	Proportion
Hydromorphone	0.83
Fentanyl	0.14
Acetaminophen	0.05
Ibuprofen	0.00
Toradol	0.00
Methocarbamol	0.27
Hydrocodone-Acetaminophen	0.01
Oxycodone-Acetaminophen	0.03
Oxycodone	0.04
Other	0.01

In PACU, the 150 spine surgery patients got between 0 and 12 doses of pain medication. The average was 3.05 doses (*SD* = 2.33), and the median was 3 doses. Looking at the most common agents administered, the total dose of fentanyl in PACU ranged from 25 mcg to 200 mcg. The dose had a mean of 84.78 mcg (*SD* = 47.52) and a median of 75 mcg. The total dose of methocarbamol in PACU ranged from 500 mg to 1000 mg. The dose had a mean of 901.16 mg (*SD* = 145.77) and a median of 1000 mg. The total dose of hydromorphone in PACU ranged from 0.25 mg to 5.0 mg. The dose had a mean of 1.52 mg (*SD* = 0.85) and a median of 1.5 mg. The average NRS score in PACU ranged from 0 to 9.60, with a mean of 4.92 (*SD* = 2.35) and a median of 5. All of these findings were very consistent with cervical spinal procedures alone.

There was no statistically significant association between the number of multimodals and the average NRS scores in PACU ($b = 0.25$, $t = 1.59$, $p = 0.113$). The association of the number of multimodals with the number of doses of pain medications in PACU was not statistically significant ($b = 0.22$, $t = 1.42$, $p = 0.158$). There were no statistically significant associations between the number of multimodals and the PACU fentanyl dose ($b = 1.60$, $t = 0.17$, $p = 0.861$),

the PACU hydromorphone dose ($b = 0.04$, $t = 0.65$, $p = 0.516$), or the PACU methocarbamol dose ($b = 12.77$, $t = 0.62$, $p = 0.538$).

None of the individual intraoperative multimodals (fentanyl, hydromorphone, methadone, ketamine, dexmedetomidine, lidocaine, magnesium, other) had a significant association with pain medication administration or NRS scores in PACU. The Pearson correlation r ranged from -0.01 to 0.13; p ranged from 0.11 to 0.86. Overall, the data agrees – multimodals given with remifentanil did not statistically influence postoperative pain medication administration or pain scores for this sample.

CHAPTER V: DISCUSSION

Discussion

This QI project sought to examine the current practices of multimodal analgesic administration when using a short-acting remifentanil infusion in cervical surgeries. The primary and secondary outcomes measured were self-reported pain scores and analgesic medication requirements in the PACU. Although there were no findings of statistical significance, comprehensive evaluation of the data found that nurse anesthetists were employing a multimodal approach to analgesia. Clinically significant, this indicates that providers were tailoring the anesthetic to each patient's needs, giving various amounts of different intraoperative analgesic medications. The practices were also largely deemed to be safe, as there were no naloxone administrations required for this sample.

The most common multimodal cocktail for cervical spinal fusions utilizing remifentanil at the project site included two adjuncts, fentanyl and hydromorphone. In PACU, patients typically got between two and three doses of pain medications, usually some combination of hydromorphone and methocarbamol. Findings showed this led to an average NRS score in PACU of 4.41. When comparing this to the larger QI project, the most common multimodal cocktail included one more intraoperative adjunct, ketamine. In PACU, patients got slightly more pain medication (three doses), but the same combination of hydromorphone and methocarbamol. The corresponding average NRS score in PACU was also higher, 4.92. Given the breakdown of intraoperative multimodal analgesics in Table 1 and Table 3, the greatest opportunities for improvement were use of lidocaine infusions, methadone, and magnesium.

Overall, there is room for practice improvement, as evidenced by the aforementioned postoperative pain scores. An average pain score of 4.41 or 4.92 is unacceptable, especially

considering some pain scores were as high as 9. Anesthesia providers must recognize which patients are at risk for higher postoperative pain and do their best to treat it with multimodal analgesics. There are surgical factors to consider such as how many levels of the spine are affected, whether a minimally invasive or invasive surgical approach is used, and provider skill level. Patient specific factors consist of preoperative narcotic use, tobacco or illicit drug history, age, and a chronic pain diagnosis. Paying greater attention to these factors preoperatively can prevent an unsatisfactory postoperative pain experience.

When comparing the data to the literature, there are two important things to note. For one, this QI project lacked a non-multimodal comparison group. For another, there were many variables to account for, both in terms of patient demographics and the various medications received in both the OR and PACU. For this reason, the data showed a lack of statistically significant association while the literature pointed to the benefit of multimodal analgesia (Silva et al., 2022). Additionally, the literature showed different benefits of each medication used, while this QI project focused solely on pain. For example, Zheng et al. (2024) found that dexmedetomidine was associated with improved pain scores as well as a quicker time to extubation. By allowing patients to meet extubation criteria faster, dexmedetomidine minimizes pain from extra time spent in bed and reduces the incidence of associated sore throat. Another study by L. Zhao et al. (2024) found that the administration of ketamine reduced the amount of remifentanil required, thereby decreasing postoperative pain scores and pain medications received. These two medications were not commonly used in the sample for this project.

Most of the literature that was reviewed looked at the association between remifentanil and one or two analgesics. Out of the two studies that looked at several analgesics hitting a variety of receptors, anesthesia providers at the level one academic medical center gave every

drug mentioned apart from paracetamol and lidocaine infusions (Silva et al., 2022; Weinberg et al., 2024). Thus, the medications examined in this QI project were consistent with current research. As such, the lack of any association was disappointing. Given the significant limitations, these findings need to be revisited.

Nevertheless, this project can positively impact patients, providers, and the system at large. By understanding the current role of multimodal analgesia in combination with remifentanil at the level one academic medical center, opportunities for improvement can be identified. This ensures providers are optimizing pain management practices and patients are given an ideal postoperative recovery experience, translating into reduced complication rates and elevated patient satisfaction scores. Additionally, by minimizing postoperative pain, the system can cut down on LOS costs and ensure optimal PACU efficiency.

Project Strengths and Limitations

Project strengths include the variation in CRNAs and MDAs administering the sampled anesthetics. As such, the analysis of multimodal analgesics did not merely represent the practices of a few, but rather the practices of many. These providers likely trained at different facilities, had different amounts of experience, and spanned a variety of demographics. Additionally, there was a significant variation in surgeons performing these procedures. This also minimized the influence of specific surgical techniques on postoperative pain scores.

One limitation of this project was the patient population. Spine surgery patients, whether it be cervical, thoracic, or lumbar, often deal with chronic pain and take several different pain medications before resorting to surgery. As a result, they often have upregulation of pain receptors and a general tolerance to narcotics (Fujii & Nishiwaki, 2022). While excluding these patients was a consideration, it would have been difficult to execute. Some patients have a

documented chronic pain diagnosis, while others do not. Additionally, it is difficult to locate a thorough medication history in EHR documentation, as these patients may see multiple doctors and often visit outside pain clinics.

Another limitation of this project was the variation in remifentanil infusions. X. Su et al. (2020) concluded that propofol-remifentanil anesthesia was superior in mitigating postoperative hyperalgesia compared to sevoflurane-remifentanil anesthesia. The use of TIVA versus non-TIVA was not accounted for in this QI project. Additionally, one study found an association between remifentanil and OIH when the remifentanil infusion was discontinued abruptly or when higher infusion doses were given (Kawanaka et al., 2022). Unfortunately, there was a considerably wide range in remifentanil doses administered in this QI project.

Given the aforementioned project limitations, it would be wise to narrow the future focus. One potential idea would be to change the surgical procedure studied to one that did not often encompass chronic pain patients, such as carotid endarterectomies. Even from there, it would be prudent to limit the sample to a specific total dose of remifentanil given (whether it be a high or low dose).

Recommendations for Clinical Practice

Based on project findings, the most opportunities for improvement can be found with lidocaine infusions, methadone, and magnesium. Finding out project site barriers to use of these medications or why these intraoperative adjuncts are not considered favorable by providers would be the next logical step. Additionally, many anesthesia providers err on the side of caution when it comes to administering these medications. More education and practice guidance (i.e. guidelines or protocols) on absolute and relative contraindications, indications for use, and appropriate intraoperative dosing could be beneficial to improve PACU pain scores.

Recommendations for Future Projects and Research

This QI project has provided a good segway to future areas for research and QI projects. Studying specific uses of different multimodal analgesics in combination with remifentanil could be beneficial to clinical practices. Future studies should look at whether hydromorphone should be given before or after turning off the remifentanil infusion. Other studies could analyze the use of remifentanil and multimodal analgesics qualitatively, using interviews or focus groups. Looking at a cost benefit analysis of remifentanil could also prove its worth, or lack thereof. Lastly, evaluation of practices and patient outcomes should be undertaken after guideline and/or provider education implementation.

Summary

This RCR sought to identify current practices for multimodal analgesia and narcotic administration in cervical spinal fusion procedures utilizing remifentanil infusions. Commonly used intraoperative medications studied included fentanyl, hydromorphone, methadone, ketamine, dexmedetomidine, lidocaine, and magnesium. After reviewing the charts of 50 patients that met inclusion criteria, there was determined to be no statistically significant association between the number of multimodals and the number of doses of pain medications in PACU or the average pain scores in PACU. Unfortunately, this leaves more questions than answers. There are no concrete take-aways regarding optimal pain regimens. More research and projects need to be conducted to see if the patient outcome data and the literature agree – that multimodal analgesia can combat OIH associated with remifentanil.

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APPENDIX A: DATA COLLECTION PLAN

Setting:
Level one academic medical center

Patient characteristics/Inclusion criteria:

- Age > or = 18 years
- Use of remifentanil infusion

Surgical types:

- Cervical spinal fusions
- Thoracic spinal fusions
- Lumbar spinal fusions

Data needed:

- 50 charts each (cervical, thoracic, and lumbar)
- Patient age
- Patient gender
- Patient race/ethnicity
- Patient American Society of Anesthesiologists (ASA) status
- Documentation of remifentanil infusion- time of initiation/discontinuation and total dose
- Documentation of any fentanyl use, timing, and dosage
- Documentation of any hydromorphone use, timing, and dosage
- Documentation of any ketamine use, timing, and dosage
- Documentation of any dexmedetomidine use, timing, and dosage
- Documentation of any methadone use, timing, and dosage
- Documentation of any lidocaine infusion use, time of initiation/discontinuation, and total dose
- Documentation of any magnesium infusion use, time of initiation/discontinuation, and total dose
- Anesthesia start and stop time
- Pain score documentation in PACU (NRS)
- Documentation of postoperative pain medication administration (to include the type, dose, time, and route)
- Time of admission to PACU and discharge from PACU (or documented handoff to floor nurse)

Exclusion criteria:

- Pregnant or parturient patients
- Minors (under the age of 18)
- Post-surgical admission to the intensive care unit (ICU)

APPENDIX B: CHART REVIEW GUIDE

Todays Date: ___/___/___ Care Nurse: (PI)_____ (PII)_____
Date of Surgery:___/___/___ MRN: _____ Completed by: _____
Pt Type: Ped Adult (circle type) Score:_____

Flowsheets Tab -Vital signs	Answer	Comments
1. Admission temperature > or = to 96.8F	Yes/No/ NA	
2. Discharge temperature > or = to 96.8	Yes/No/ NA	
3. Temperature is documented every 1 hour	Yes/No/ NA	
4. If temperature is < 96.8F, temp is rechecked in 15 minutes and interventions documented every 30 minutes until normothermic. **Document intervention in PACU Intervention section: Additional comfort/enviromental interventions.**	Yes/No/ NA	
5. Vital signs are documented at least Q 15 minutes while in Phase I and Q 1 hour Phase II	Yes/No/ NA	
6. O2 sats are > or = 92% on transfer or appropriate MD order obtained	Yes/No/ NA	
Flowsheets Tab- Pain Assessment	**Answer**	**Comments**
7. Pain assessments are documented on admission and at least every 30 minutes while in Phase I and every 1 hour in Phase II	Yes/No/ NA	
8. Pain assessment is completed on discharge and is within 0-4 pain scale	Yes/No/ NA	
9. Patient remains in Phase I for a minimum of 20 minutes or Phase II for 30 minutes after IV narcotic administration; remain in PACU (I & II) 20 minutes after oral narcotic administration.	Yes/No/ NA	
10. PRN response to pain medication admistered is documented within 20 minutes	Yes/No/ NA	
Flowsheets Tab- Sedation Scales	**Answer**	**Comments**
11. Pasero Opiod Induced Sedation Scale (POSS) score documented before and after opioid administration with pain assessment (adults)	Yes/No/ NA	
. Richmond Agitation Sedation Scale (RASS) on admission, with changes, and at discharge	Yes/No/ NA	
Flowsheet Tab- Oxygen Therapy	**Answer**	**Comments**
13. Patient on RA at least 10 minutes before transfer to Phase II	Yes/No/ NA	
Flowsheet Tab- Assessment Bands	**Answer**	**Comments**
14. Admission Assessment (all applicable bands complete) **Glascow Coma Scale found in the Complex Assessment Flowsheets**	Yes/No/ NA	
15. Adult patients remain in PACU until the Aldrete score is 10 , or permission from MDA if <10	Yes/No/ NA	
16. Peds patients remain in PACU (I & II) minimum 60 minutes from ETT/LMA, all others 30 min	Yes/No/ NA	
17. 60 minute re-assessment completed to include LOC and surgical site/s and drains	Yes/No/ NA	
18. Aldrete score completed on admission & discharge to Phase I	Yes/No/ NA	
19. Aldrete score completed on admission & discharge to Phase II	Yes/No/ NA	
20. Presence of type armbands, bed position/wheels, side rails/bed safety, non skid footwear-on admission to Phase I & Phase II- **Daily Cares/Safety flowsheet**	Yes/No/ NA	
SPINAL/EPIDURAL ANESTHESIA PATIENTS		
21. Dermatone level documented every 30 minutes (every 15 minutes if T4 or above)	Yes/No/ NA	
22. Increase in HOB is documented	Yes/No/ NA	
23. Once HOB 30°,"sitting SBP" is within 20mmHG of "lying SBP" & HR doesn't increase by >20bpm, no bradycardia, sensory < or = to T10	Yes/No/ NA	
Flowsheet Tab- Intake/Output	**Answer**	**Comments**
24. I&O are documented every 1 hour- Phase I	Yes/No/ NA	

Scoring: Each item =3 points- All NA are scored as a Yes.
Scoring example: 2 items missed (6 points) 100-6=94

Initiated 2018
Revised 2022

PACU Tab- Use the "jump to" arrow to find documented data	Answer	Comments
25. Care Plan Nursing Dx, Goals, Outcomes documented for Phase I patients	Yes/No/ NA	
26. Phase I CRNA to Nurse Handoff (all handoffs can be seen here or discharge tab)	Yes/No/ NA	
27. Phase II Nurse Handoff	Yes/No/ NA	
28. Discussion with MDA documented for EBL >1000ml in Nursing Notes in Phase I- or Chart Review/Notes	Yes/No/ NA	
Education Tab	**Answer**	**Comments**
29.Education assessment completed	Yes/No/ NA	
30. Short stay /Procedure education documented	Yes/No/ NA	
Discharge Tab-Use the "jump to" arrow to find documented data	**Answer**	**Comments**
31. Care Plan Nursing Dx, Goals, Outcomes documented for Phase II patients	Yes/No/ NA	
32. Discharge Checklist completed- Discharge planning	Yes/No/ NA	
33. Opioid safe use education if sent home with opioid prescription -Instructions	Yes/No/ NA	
MAR Tab	**Answer**	**Comments**
34. REVIEW MAR- 2nd Witness -Click to see more details and then hover over the date/time beside "recent actions" or select the Product order report (2 intertwined boxes at end of medication name on MAR) For medications requiring a 2nd witness, witnessed and documented per policy. Note: All peds <40kg require weight based dosing which requires 2 witnesses to verfiy MD order as prescribed, correct dosage and calculation. Peds meds requiring 2 witnesses include all listed below and all controlled substances and narcotics. 1. Require witness for correct dosage and co-signature documented on MAR by 2 licensed nurses: Insulin, hyperalimentation, anticoagulants (heparin, coumadin (warfarin). 2. Require witness by 2 licensed nurses to verify dose, drug calculation, and verification of order as prescribed: Heparin & LMWHS (lovenox), direct thrombin inhibitors, thromobolytic agents, paralytic agents, insulin, biotherapy medications, chemotherapy medications, coumadin, digoxin, and hyperalimentation.	Yes/No/ NA	

Scoring: Each item =3 points- All NA are scored as a Yes.
Scoring example: 2 items missed (6 points) 100-6=94

Initiated 2018
Revised 2022

APPENDIX C: REDCAP DATA DICTIONARY

Team Remi Data Collection

Please complete the survey below.

Thank you!

1) Deidentifed Number

_____
(101-150 - cervical spinal fusions; 151-200 - thoracic spinal fusions; 201-250 - lumbar spinal fusions)

2) Treatment Group

◯ cervical spinal fusions
◯ thoracic spinal fusions
◯ lumbar spinal fusions

3) Patient Age

_____
(Whole number (in years))

4) Patient Gender

◯ Male
◯ Female
◯ Other

5) Patient Race/Ethnicity

◯ White
◯ Hispanic/Latino
◯ Black
◯ Asian
◯ Other/Unknown

6) Patient ASA Status

◯ 1
◯ 2
◯ 3
◯ 4
◯ 5
◯ 6

7) Time of Remifentanil Initiation

_____
(Whole number denoted in military time from 0000 to 2359)

8) Time of Remifentanil Discontinuation

_____
(Whole number denoted in military time from 0000 to 2359)

9) Entire Remifentanil Dose

_____
(Denoted as a number with two decimal places in mg)

10) Intraoperative Adjuncts

☐ Fentanyl
☐ Hydromorphone
☐ Methadone
☐ Ketamine
☐ Dexmedetomidine
☐ Lidocaine
☐ Magnesium
☐ Other

11) Fentanyl Administration Time(s) Intraoperatively

_____
(Whole number denoted in military times from 0000 to 2359, with commas separating entries)

12) Total Fentanyl Administration Intraoperatively

_____
(Whole number denoted in micrograms)

13) Hydromorphone Administration Time(s) Intraoperatively

_____
(Whole number denoted in military times from 0000 to 2359, with commas separating entries)

14) Total Hydromorphone Administration Intraoperatively

_____
(Denoted as a number with two decimal places in mg)

15) Methadone Administration Time(s) Intraoperatively

_____
(Whole number denoted in military times from 0000 to 2359, with commas separating entries)

16) Total Methadone Administration Intraoperatively

_____
(Whole number denoted in milligrams)

17) Ketamine Administration Time(s) Intraoperatively

_____
(Whole number denoted in military times from 0000 to 2359, with commas separating entries)

18) Total Ketamine Administration Intraoperatively

_____
(Whole number denoted in milligrams)

19) Dexmedetomidine Administration Time(s) Intraoperatively

_____
(Whole number denoted in military times from 0000 to 2359, with commas separating entries)

20) Total Dexmedetomidine Administration Intraoperatively

_____
(Whole number denoted in micrograms)

21) Time of Lidocaine Infusion Initiation

_____
(Whole number denoted in military time from 0000 to 2359)

22) Time of Lidocaine Infusion Discontinuation

_____
(Whole number denoted in military time from 0000 to 2359)

23) Entire Lidocaine Infusion Dose

_____
(Denoted as a number with two decimal places in mg)

24) Time of Magnesium Infusion Initiation

_____
(Whole number denoted in military time from 0000 to 2359)

25) Time of Magnesium Infusion Discontinuation

_____
(Whole number denoted in military time from 0000 to 2359)

26) Entire Magnesium Infusion Dose

_____
(Denoted as a number with two decimal places in g)

27) Anesthesia Start Time

_____
(Whole number denoted in military time from 0000 to 2359)

28) Anesthesia Stop Time

_____
(Whole number denoted in military time from 0000 to 2359)

29) Time of PACU Admission

_____
(Whole number denoted in military time from 0000 to 2359)

30) Time of PACU Discharge

_____
(Whole number denoted in military time from 0000 to 2359)

31) First PACU NRS Score

_____

32) PACU NRS Score Corresponding to First Pain Medication Administration

_____

33) PACU NRS Score Corresponding to Second Pain Medication Administration

_____

34) PACU NRS Score Corresponding to Third Pain Medication Administration

_____

35) PACU NRS Score Corresponding to Fourth Pain Medication Administration

_____

36) Final PACU NRS Score

_____

37) Pain Medications Received in PACU

☐ Hydromorphone
☐ Fentanyl
☐ Acetaminophen
☐ Ibuprofen
☐ Toradol
☐ Methocarbamol
☐ Hydrocodone-Acetaminophen (5-325 mg per tablet)
☐ Oxycodone-Acetaminophen (5-325 mg per tablet)
☐ Oxycodone (5 mg per tablet)
☐ Other

38) Total Instances of Pain Medication Administration in PACU

_____
(Whole number, 0 or higher)

39) Total Dose Fentanyl in PACU

_____
(Whole number denoted in mcg)

40) Total Dose Hydromorphone in PACU

_____
(Denoted as a number with two decimal places in mg)

41) Total Dose Methocarbamol in PACU

_____
(Whole number denoted in mg)

42) First Pain Medication Received in PACU

☐ Hydromorphone
☐ Fentanyl
☐ Acetaminophen
☐ Ibuprofen
☐ Toradol
☐ Methocarbamol
☐ Hydrocodone-Acetaminophen (5-325 mg per tablet)
☐ Oxycodone-Acetaminophen (5-325 mg per tablet)
☐ Oxycodone (5 mg per tablet)
☐ Other

43) First Dose of Pain Medication Received in PACU

_____
(Corresponding dose to three decimal places in mg/ number of tablets)

44) First Route of Pain Medication Received in PACU

◯ oral
◯ IV
(Corresponding dose to two decimal places in mg)

45) Time of First Pain Medication Received in PACU

_____
(Whole number denoted in military time from 0000 to 2359)

46) Second Pain Medication Received in PACU

☐ Hydromorphone
☐ Fentanyl
☐ Acetaminophen
☐ Ibuprofen
☐ Toradol
☐ Methocarbamol
☐ Hydrocodone-Acetaminophen (5-325 mg per tablet)
☐ Oxycodone-Acetaminophen (5-325 mg per tablet)
☐ Oxycodone (5 mg per tablet)
☐ Other

47) Second Dose of Pain Medication Received in PACU

_____
(Corresponding dose to three decimal places in mg/ number of tablets)

48) Second Route of Pain Medication Received in PACU

◯ oral
◯ IV
(Corresponding dose to two decimal places in mg)

49) Time of Second Pain Medication Received in PACU

_____
(Whole number denoted in military time from 0000 to 2359)

50) Third Pain Medication Received in PACU

☐ Hydromorphone
☐ Fentanyl
☐ Acetaminophen
☐ Ibuprofen
☐ Toradol
☐ Methocarbamol
☐ Hydrocodone-Acetaminophen (5-325 mg per tablet)
☐ Oxycodone-Acetaminophen (5-325 mg per tablet)
☐ Oxycodone (5 mg per tablet)
☐ Other

51) Third Dose of Pain Medication Received in PACU

_____
(Corresponding dose to three decimal places in mg/ number of tablets)

52) Third Route of Pain Medication Received in PACU

◯ oral
◯ IV
(Corresponding dose to two decimal places in mg)

53) Time of Third Pain Medication Received in PACU

_____
(Whole number denoted in military time from 0000 to 2359)

54)	Fourth Pain Medication Received in PACU	☐ Hydromorphone ☐ Fentanyl ☐ Acetaminophen ☐ Ibuprofen ☐ Toradol ☐ Methocarbamol ☐ Hydrocodone-Acetaminophen (5-325 mg per tablet) ☐ Oxycodone-Acetaminophen (5-325 mg per tablet) ☐ Oxycodone (5 mg per tablet) ☐ Other
55)	Fourth Dose of Pain Medication Received in PACU	_____ (Corresponding dose to three decimal places in mg/ number of tablets)
56)	Fourth Route of Pain Medication Received in PACU	◯ oral ◯ IV (Corresponding dose to two decimal places in mg)
57)	Time of Fourth Pain Medication Received in PACU	_____ (Whole number denoted in military time from 0000 to 2359)

APPENDIX D: UNIVERSITY IRB DETERMINATION

To:	Amy Adams University of North Carolina at Charlotte
From:	Office of Research Protections and Integrity
Date:	27-May-2024
RE:	Determination that Activity is not Research and does not require IRB Approval
Study #:	IRB-24-1056
Study Title:	Hydromorphone Administration Timing in Surgeries Utilizing Remifentanil

This submission was reviewed by the Office of Research Protections and Integrity, which has determined that this submission does not constitute research as defined under federal regulations 45 CFR 46.102(l) and 21 CFR 56.102(c) and/or (l) and does not require IRB approval.

Study Description:

RATIONALE: The timing, dosage, and choice of intraoperative pain medication can impact patient outcomes in the postoperative care unit (PACU). Remifentanil, a unique opioid with both rapid onset and metabolism, is frequently used for cases requiring quick anesthetic onset or offset, supplemental immobility when paralytic is contraindicated, or total intravenous anesthesia (TIVA). Suboptimal analgesic administration may result in longer times of anesthetic emergence, higher PACU pain scores, greater length of PACU stay, and increased nausea and/or vomiting (PONV). While current textbooks recommend administration of a long-acting opioid before discontinuation of a remifentanil infusion, multiple factors influence provider decision, and there is no concise guideline on this practice. PURPOSE: This quality improvement (QI) project seeks to identify if specific intraoperative administration timing of hydromorphone, a long-acting opioid, in relation to remifentanil infusion discontinuation is associated with improved patient outcomes in the postoperative period. Anesthesia providers at Atrium Health – Carolinas Medical Center (CMC) and One Day Surgery (ODS) utilize remifentanil most often in thyroidectomy, spinal fusion, and carotid enterectomy surgeries. Analyzing current practice in comparison to evidence-based literature may provide suggestions to optimize patient care and safety. METHODS: Guided by the Plan-Do-Study-Act (PDSA) model, this QI project will conduct a retrospective chart review from July 2023 to June 2024, including adults over the age of 18 years undergoing thyroidectomies, spinal fusions, or carotid endarterectomies. 100 charts will be selected for each surgery, with 50 documenting hydromorphone administration before remifentanil infusion discontinuation and 50 documenting hydromorphone administration after remifentanil infusion discontinuation. Data collection from the electronic health record (EHR) will include but is not limited to numerous patient variables, surgical and anesthetic start and stop times, and postoperative self-reported pain scores, pertinent medication administration, and length of stay. A Microsoft Excel codebook will categorize the data to ensure consistency and accuracy for analysis. OUTCOMES: The anticipated outcomes aim to improve care quality, postoperative pain management and patient recovery at the project sites by comparing outcomes in hydromorphone timing with remifentanil discontinuation. Key outcomes will include hydromorphone dosage timing associated with the shortest PACU length of stay and lowest PACU self-reported pain scores. Additionally, secondary postoperative outcomes will include PONV, naloxone use for opioid overdose, and the need for pain medications in the PACU.

You must inform the IRB office of any changes to the project so that it can be determined whether the changes impact this determination.

This determination did not include consideration of HIPAA requirements. If this project involves activities that are subject to HIPAA (e.g., access to or use of protected health information), it is your responsibility to obtain approval from the HIPAA covered entity and comply with all applicable requirements.

Please be aware that approval may still be required from other relevant authorities or "gatekeepers" (e.g., school principals, facility directors, custodians of records).

Niner Research IRB (sent by crunden@charlotte.edu) Wed, Jul 31, 12:32 PM (7 days ago)

to Kelly, me

Dear Payton,

This project received a Non-Human Subjects Research determination because it is a QI/QA project. This determination is not the equivalent of IRB review or approval.

If the changes to the project will impact the Non-Human Subjects Research determination such that the project will now be Human Subjects Research, you would need to submit an Initial Application for IRB review.

If the changes to the project do not impact the Non-Human Subjects Research determination, no action with the UNCC IRB office is needed.

However, since your project also required review by the Wake Forest/Atrium IRB office, you should reach out to that office to determine what actions are needed given the proposed changes to the project.

Thanks.
Cat

Office of Research Protections and Integrity
Institutional Review Board (IRB)
UNC Charlotte | Cameron 326 and 301
9201 University City Blvd., Charlotte NC 28223
Phone: 704-687-1871 | Fax: 704-687-0980
uncc-irb@charlotte.edu | CatRunden@charlotte.edu | tforgett@charlotte.edu

APPENDIX E: MEDICAL CENTER IRB APPROVAL

IRB APPLICATION APPROVED

To:	Amy Adams
Study Title:	Hydromorphone Administration Timing with Remifentanil
IRB #:	IRB00114557
PI:	Karen Lucisano
Link to Workspace:	IRB00114557

PLEASE DO NOT RESPOND TO THIS EMAIL- Call (336) 716-4542 if you have questions.

The Insitutional Review Board has reviewed and approved the above referenced research study. Please use the "Link to Workspace" above to access the approval memo, consent forms, assent forms, and other items associated with this study.

Advocate Health - Wake Forest University School of Medicine Institutional Review Board WFUHS: (336) 716-4542

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