Intravenous Magnesium Sulfate Use in Hip Arthroscopy Patients and Anesthesia Provider Satisfaction with Patient Care at an Ambulatory Surgery Center

Naomi Song
*University of Pennsylvania, nsong@upenn.edu*

Erica Yi
*University of Pennsylvania*

Julianne Bagley
*University of Pennsylvania*

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Abstract
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Keywords
magnesium, anesthesia, perioperative, multimodal analgesia, provider satisfaction

Disciplines
Anesthesiology | Nursing | Perioperative, Operating Room and Surgical Nursing

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Julianne Bagley, Naomi Song, and Erica Yi

School of Nursing, University of Pennsylvania
Abstract

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The purpose was to add IV magnesium sulfate to the multimodal analgesic pathway for hip arthroscopy patients to evaluate anesthesia provider satisfaction and use of IV magnesium sulfate. The Middle Range Theory of Acute Pain was used to provide a theoretical framework.

The conceptual framework utilized was the Plan-Do-Study-Act cycle. Anesthesia providers were refamiliarized with IV magnesium sulfate's analgesic properties to encourage its administration in hip arthroscopy procedures yielding high levels of postoperative pain. A survey was distributed to assess provider satisfaction using the Accessibility of Intervention Measure (AIM) and magnesium use. Frequency counts were used to determine provider satisfaction with patient care and a run-chart was created to analyze changes in IV magnesium sulfate usage before and after implementation. Compared to the pre-implementation phase, there was an 85.7% increase in IV magnesium use among anesthesia providers. Over 12 weeks, ten CRNAs participated in a total of fourteen hip arthroscopy cases. Nine out of ten providers would consider using magnesium in future practice. The project served to re-introduce IV magnesium sulfate as an analgesic adjunct for many surgical procedures and hoped to promote a culture that utilizes IV magnesium sulfate readily.

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Multimodal analgesia is now the desired approach for managing perioperative pain, as heavy opioid administration is discouraged for its addictive nature and undesirable adverse effects. Numerous studies have shown that magnesium sulfate, among other agents, is a powerful analgesic adjunct. When used intraoperatively, magnesium sulfate can help reduce postoperative pain and opioid consumption. This will decrease recovery times, improve patient satisfaction, decrease healthcare costs, and lighten the burden of the opioid crisis.

Background and Significance

Postoperative pain is associated with delayed recovery, decreased patient satisfaction, prolonged hospitalizations, and increased healthcare costs (Mitra et al., 2018) when managed poorly. Undertreated pain at the time of surgery predisposes patients to post-surgical pain and long-term neuropathic pain (Mitra et al., 2018; Ramaswamy & Colvin, 2013). Historically, opioids have been the primary analgesic agent used in the perioperative period, but its use is limited by their adverse effects especially when used as the sole analgesic agent. Perioperative use of opioids increases the incidence of postoperative nausea and vomiting (PONV), dose-dependent respiratory depression, delayed emergence from anesthesia, and physical dependence (Mitra et al., 2018). Opioid use is also associated with adverse side effects such as pruritus, urinary retention, ileus, constipation, dysphoria, and muscle rigidity (Yaster et al., 2017). More recently, there have been reports of dose-dependent hyperalgesia, paradoxical acute and chronic pain, and immunomodulation effects (Mitra et al., 2018; Ramaswamy & Colvin, 2013; Beloeil, 2019) with opioid use. Older adults, chronically ill patients, and pregnant women are especially...
vulnerable to developing such side effects. Furthermore, the persistent concerns regarding the opioid crisis in North America have increased the interest in developing techniques to replace or reduce opioid use perioperatively.

Multiple variables contribute to postoperative pain. To date, no single pharmacological agent has proven to be effective in decreasing postoperative pain scores without significant side effects (Ziemann-Gimmel et al., 2014). Over the last decade, multimodal analgesia (MMA) has emerged as the gold standard of perioperative analgesia. It is associated with reduced perioperative opioid use, decreased rates of adverse effects, stable intraoperative hemodynamic reactions, early mobilization, and reduced risks of chronic opioid use (Mitra et al., 2018; Yaster et al., 2017). MMA promotes the use of various agents targeting different pain receptors and pathways to achieve a synergistic analgesic effect. It has become an essential component in the Enhanced Recovery after Surgery (ERAS) or Opioid-Free Anesthesia (OFA) protocols (Shipton et al., 2018; Beloeil, 2019; Yaster et al., 2017). Several non-opioid based adjuncts have been frequently used, including ketamine, lidocaine, nonsteroidal anti-inflammatory drugs (NSAIDs), dexmedetomidine, gabapentinoids, neuraxial anesthesia, and peripheral nerve blocks (Mitra et al., 2018; Ramaswamy & Colvin, 2013; Beloeil, 2019).

Magnesium sulfate is an agent that has been widely used as a powerful analgesic adjunct due to its ability to antagonize N-methyl-D-aspartate (NMDA) receptors. Studies have demonstrated its effectiveness in stabilizing perioperative hemodynamics (Herroeder et al., 2011). A large number of clinical studies have shown the effectiveness of intraoperative administration of magnesium in decreasing opioid consumption and improving postoperative pain outcomes in a variety of procedures (Herroeder et al., 2011; Na et al., 2011). The American Society of Regional Anesthesia and Pain Medicine recommends incorporating the intraoperative
administration of intravenous (IV) magnesium sulfate as an analgesic adjunct in perioperative care (George et al., 2018). Magnesium is effective in blunting somatic and autonomic reflexes by inhibiting catecholamine release associated with surgery. In addition, it reduces intraoperative anesthetic consumption and decreases muscle relaxant requirements (Herroeder et al., 2011; Na et al., 2011; Do, 2013; Rodríguez-Rubio et al., 2017). All of the benefits of magnesium sulfate make it a favorable option for intraoperative use.

The number of hip arthroscopy cases has increased in the recent decade, attributed to its wide variety of indications to see a magnified view of the joint in a minimally invasive way. Patients are typically discharged from the Post Anesthesia Care Unit (PACU) the same day if no complications arise. However, despite being minimally invasive, there is a wide range of reported postoperative pain scores after hip arthroscopy. Ward et al. (2012) reported 90% of patients who experience moderate to severe pain after hip arthroscopy was due to manipulation of the intra-articulated compartment with different sensory nerves that innervate the hip joint such as the femoral, obturator, and sciatic nerves. Pain could also be due to the traction pressure caused by irrigation fluids. The swelling after surgery can further increase pain and delay healing (Bech et al., 2016). Undertreated pain delays PACU discharge, decreases patient satisfaction, as well as provider satisfaction in patient care. Therefore, with supporting evidence, this quality improvement proposal calls for the inclusion of magnesium sulfate in a multimodal analgesic pathway for patients undergoing hip arthroscopy.

**Problem Statement and Clinical Question**

Hip arthroscopy patients experience high levels of postoperative pain, leading to increased rescue analgesic consumption and decreased patient satisfaction. Magnesium sulfate is widely used in anesthesia practice as a multimodal analgesic but is infrequently utilized at Penn
Presbyterian Medical Center. Does adding IV magnesium sulfate to the current multimodal analgesic pathway increase magnesium use and provider satisfaction with patient care?

**Literature Review**

**Methods**

This review was guided by the integrative review methodology outlined by Whittemore and Knafl (2005), which provided a research framework to combine and analyze diverse data utilizing evidence such as integrative reviews, systematic reviews, and meta-analysis. This multi-step research strategy allowed for complex perspectives and clinical findings to be synthesized into one comprehensive review for the topic of interest, which can then be used as the basis for clinical practices.

Our literature search, article selection, and evaluation were guided by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Appendix D). A literature search was conducted using two electronic databases: PubMed and Embase. The following National Library of Medicine Medical Subject Heading (MeSH) terms and keywords were used in PubMed, ("Surgical Procedures, Operative"[Mesh]) OR "Surgery Department, Hospital"[Mesh]) OR "Intraoperative Period"[Mesh] OR perioperative* OR operative OR intraoperative* OR postoperative OR postop*) AND ("Magnesium Sulfate") AND (IV OR intravenous OR infusion) AND (anesthesia OR anaesthesia OR "Anesthesia, General"[Mesh] OR "Anesthesia"[Mesh] OR "Anesthesia and Analgesia"[Mesh]) AND (pain OR pain*). After limiting the search to articles that studied the adult population and were written in the English language, PubMed yielded 42 articles. The following search strategy was used in Embase: (surgery OR surgical OR intraoperative OR perioperative OR 'general anesthesia'/exp OR 'procedures'/exp) NOT 'obstetric procedure'/exp NOT 'pregnancy'/exp AND 'magnesium
sulfate'/exp AND infusion AND ('analgesia'/exp OR pain). After the results were filtered by the adult population, Embase yielded 159 articles. Articles from PubMed and Embase were exported to RefWorks and 15 duplicates were removed. The titles and abstracts of the 186 articles were screened independently by the project leaders of this review based on the inclusion and exclusion criteria.

Inclusion criteria included 1) articles written in English; 2) studies sample defined as adult population; 3) search terms found in the title or within keywords; 4) studies of IV magnesium sulfate administration compared to placebo or another analgesic agent; 5) studies of intraoperative magnesium administration. Exclusion criteria included 1) articles related to non-adult populations; 2) case studies, commentaries, clinical review articles, editorials; 3) studies of magnesium administration outside of the intraoperative period; 4) studies with the experimental group being non-IV magnesium as a route of administration. This search strategy yielded 82 articles and excluded 104 articles. After reading full-text articles and excluding studies published before 2015, a total of 38 articles were chosen. A total of ten articles were included in the Table of Evidence and were graded using the Johns Hopkins Nursing Evidence-Based Practice Research Appraisal Guidelines (Philbrick, 2013). The design and quality of evidence of the articles were assigned an evidence level of I, II, III, IV, or V and graded A (high quality) B (good quality), or C (low quality or major flows) (Table 2).

All 38 articles selected were quantitative studies and were published between 2015 to 2020. Thirty-six articles were double-blind randomized control trials (RCT), one was an observational study, and one was a prospective cross-sectional study. For the ten studies included in the Table of Evidence, the effect of IV magnesium sulfate administration on postoperative pain was compared to either placebo (normal saline) or other analgesic adjunct(s). Of the ten
studies, seven measured postoperative pain scores using the Visual Analogue Scale (VAS), and one used the Numeric Rating Scale (NRS). These seven studies also measured secondary outcomes such as magnesium's effect on tourniquet-induced pain, sensory and motor blockade of neuraxial anesthesia, and postoperative analgesia consumptions. The two studies that did not measure postoperative pain using VAS or NRS measured the consumption of PCA and rescue analgesia, pulmonary function test results, and length of mechanical ventilation. The Synthesized Table of Evidence (Table 1) compares various populations, anesthetic type, magnesium treatment, evaluation time, and measurement.

Of the studies reported, three themes were identified and analyzed: 1) the effect of IV magnesium sulfate administration on postoperative pain scores and analgesic requirements; 2) onset and duration of perioperative analgesia from magnesium and 3) the long-term benefits of pain control to overall health. IV magnesium sulfate was selected as the choice of analgesic adjunct to add to the current analgesic pathway due to these various benefits.

Findings

Literature suggests IV magnesium sulfate to be an effective analgesic adjunct for various surgical procedures. A bolus and/or infusion of magnesium decreases pain scores, PCA consumption, and rescue analgesic consumption in adult surgical patients undergoing either general or neuraxial anesthesia.

Dehkordy et al. (2020) conducted a double-blind RCT in adult patients who underwent posterior lumbar surgery. In the RCT, patients were randomly assigned to receive a magnesium bolus of 50mg/kg and a continuous infusion of 15mg/kg/h throughout the operation; or the control group, to receive the same volume in isotonic saline. Dehkordy et al. (2020) found that in adult surgical patients undergoing posterior lumbar surgery, the PCA morphine consumption was
significantly lower in patients who received the IV bolus and infusion of magnesium sulfate compared to the control group, who received only isotonic saline. A similarly structured RCT was conducted by Jarahzadeh et al. (2016) and studied IV magnesium sulfate's analgesic effects on patients undergoing a total abdominal hysterectomy (TAH). Pain scores measured with VAS were significantly lower up to six hours after TAH and opioid requirements decreased within the group that received a magnesium sulfate bolus and infusion intraoperatively (Jarahzadeh et al., 2016). Pain scores measured with VAS and postoperative PCA morphine requirements also decreased after a bolus and infusion of magnesium in women having a cesarean section under general anesthesia (Mireskandari et al., 2015).

An IV magnesium sulfate infusion not only effectively decreased pain scores in patients undergoing general anesthesia, but also in those receiving regional anesthesia. Shah et al. (2016) conducted an RCT to determine the analgesic effects of magnesium sulfate on adult patients undergoing lower abdominal or lower limb surgery with spinal anesthesia. Postoperative pain scores assessed with VAS and rescue analgesic requirements were significantly lower in patients who had received a magnesium sulfate bolus and infusion, compared to patients who only received normal saline with their spinal anesthetic (Shah et al., 2016). Sahar et al. (2017) performed a similar RCT to assess whether IV magnesium sulfate attenuates tourniquet pain and reduces postoperative analgesic requirements in patients undergoing arthroscopic knee surgery with epidural anesthesia. The study found that in the patients who received a bolus and infusion of magnesium sulfate, tourniquet pain and intraoperative fentanyl requirements were decreased, as well as postoperative analgesic requirements (Sahar et al., 2017).

After an in-depth review of the literature, research suggests that intraoperative IV magnesium sulfate attenuates pain. Research studies were conducted on a variety of surgical
procedures, including orthopedics, bariatric, thoracic, and transplant surgery. Research studies mostly included the American Society of Anesthesiologist (ASA) class I-II of adult ranges. Exclusion criteria included hepatic, cardiovascular, renal dysfunction, neuromuscular diseases, coagulopathy, pre-existing pain syndromes, opioid abuse, prior treatment with calcium channel blockers or beta-blockers, heart blocks, hypermagnesemia, or an allergy to the treatment drug. Across research studies, intraoperative IV magnesium sulfate treatment included either a bolus dose of 30-50 mg/kg, an infusion of 10-15 mg/kg/h, or both. Postoperatively, pain scores and analgesic requirements were monitored for four to forty-eight hours.

All research studies within the literature review displayed decreases in pain scores and analgesic requirements postoperatively. Many studies displayed significant decreases in pain scores and analgesic requirements throughout the postoperative evaluation period for groups that received IV magnesium. One exception to this was found within the Taheri et al. (2015) study involving women undergoing a TAH with general anesthesia. The study group received a single magnesium bolus of 50mg/kg within 15 minutes of induction while the control group received a normal saline bolus. The study found that postoperative pain scores were significantly lower in the study group at 6, 12, and 24-hour time intervals, but there were no significant differences at the time of emergence. Despite these findings, analgesic requirements were significantly lower in the study group throughout the entire 24-hour postoperative period.

The current multimodal analgesic pathway for patients undergoing hip arthroscopy procedures includes a fascia iliaca nerve block. The use of peripheral nerve blockade for hip arthroscopy provides early postoperative pain control, minimizes opioid consumption, and facilitates discharge from the ambulatory surgical center with high-quality pain relief and overall patient satisfaction (Krych et al., 2014). Fascia iliaca blocks involve injecting a local anesthetic
into the fascia iliaca compartment, anesthetizing the articular branches of the femoral, lateral femoral cutaneous, and obturator nerves that innervate the hip capsule and related structures that are traumatized during hip arthroscopy (Kunze et al., 2020). Studies of hip arthroscopies utilizing fascia iliaca blocks have shown to provide adequate pain control and decreased opioid use after hip arthroscopy, with minimal complications (Kay et al., 2016). However, despite utilization of the fascia iliaca block, patients still report significant levels of pain and often require additional opioid consumption in the immediate postoperative period. Including IV magnesium sulfate as an additional adjunct addresses the issue of significant postoperative pain encountered with the fascia iliaca block, improving the current multimodal pathway.

**Limitations**

Limitations found in the literature review include small sample sizes and varying methods of magnesium administration. Determining the optimal method of administration (bolus dose vs. continuous infusion, weight-based dosing vs. set dose) was inconclusive. It was also unknown as to whether patients were naïve or opioid-tolerant based on the studies. Despite these factors, the collective research on intraoperative magnesium sulfate administration suggests analgesic effects potent enough to decrease pain scores and reduce opioid requirements, in addition to many other potential benefits. Regardless of surgery type and the various routes of magnesium administration used among 38 studies, the profound effect on analgesia up to 48 hours into the postoperative period remained consistent throughout the literature.

**Organizational Assessment**

Penn Presbyterian Medical Center (PPMC) is a level I trauma center nestled in the heart of University City. It is a hospital owned by Penn Medicine that largely serves the West Philadelphia community. PPMC strives to improve the health and well-being of people through
research, education, clinical care, and community service. The institution seeks to embrace the opportunity to teach others, learn from their partners, and provide care with dignity and skill. Within the Penn Medicine University City building is an Ambulatory Surgery Center (ASC), which holds the same values as its parent hospital, PPMC. Anesthesia providers at PPMC also provide anesthesia care at ASC. Due to the ambulatory nature and necessity of same-day discharge at this site, pain management is narcotic-limited and NSAID-heavy. Anesthesia providers err on the side of caution with opioid administration to prevent postoperative respiratory depression, a major factor contributing to delays in discharge. The current multimodal analgesic pathway for hip arthroscopy patients at this ambulatory surgery center includes general anesthesia with a fascia iliac block. The dosage and choice of intravenous analgesic administration varies among anesthesia providers. In general, IV magnesium sulfate is inconsistently used by anesthesia providers.

A needs assessment of the organization and problem severity were analyzed. Upon discussion with a staff member at the surgical center, it was discovered that hip arthroscopy procedures were known to cause much pain and discomfort for these surgical patients. Our needs assessment revealed that hip arthroscopy patients had high rates of postoperative pain, which decreased provider satisfaction with their anesthetic care and had implications on discharge time and postoperative pain scores. Magnesium sulfate had been inconsistently used at PPMC, although some providers did use it in various surgical procedures. Adding the option of IV magnesium sulfate to the current multimodal analgesic pathway served as a reminder to providers of this analgesic adjunct that had already been proven to efficaciously promote multimodal analgesia and had been widely utilized in other departments and healthcare facilities.
Some internal factors that impacted the project included finding a surgeon whose goals aligned with this project, was willing to accept this project for their cases, and the availability of IV magnesium sulfate at the ambulatory surgery center.

Key stakeholders of this quality improvement project included: the PPMC Director of Anesthesia (Dr. Mark Pizzini), the chief CRNA (Ed Czerpak MSN), PPMC site lead (Dr. Badiola), University of Pennsylvania faculty lead (Dr. Holly Brogan), orthopedic surgeon (Dr. John Kelly), the Pharmacy Department, anesthesia providers, and patients. While all key stakeholders had an impact on the project, pharmacy and anesthesia were impacted the most. A positive response to the addition of IV magnesium sulfate to the multimodal analgesic pathway increased intraoperative use of magnesium sulfate, the pharmaceutical workload, and cost, both from staff resources and the drug itself. The hope was to increase provider satisfaction of patient care related to hip arthroscopy and reintroduce this analgesic to the community of anesthesia providers, therefore increasing its usage for surgical patients. While the project may have long-term impact on anesthesia provider practice, the immediate outcome was to increase provider satisfaction with patient care and consideration of IV magnesium sulfate use for analgesic purposes.

**Project Purpose**

Magnesium sulfate was inconsistently utilized for multimodal analgesia at PPMC. By adding IV magnesium sulfate as an optional adjunct to the current multimodal analgesic pathway for hip arthroscopy patients, the project leaders hoped to increase IV magnesium sulfate use in the perioperative setting and provider satisfaction on patient care at PPMC. The goal was to heighten awareness of IV magnesium sulfate as a readily available and appropriate non-opioid
Conceptual and Theoretical Framework

The Plan-Do-Study-Act (PDSA) cycle was utilized in this project. The project leaders established a plan for change, carried out the plan, observed the outcome, determined effectiveness, and made modifications to conceive a final plan for the next cycle (Langley et al., 1996).

Conceptual Framework

Plan

The project leaders recognized that IV magnesium sulfate is a highly effective multimodal analgesic that is widely used in anesthesia practice but was inconsistently used at PPMC. Patients undergoing hip arthroscopies experience high levels of pain at Penn Medicine University City’s ambulatory surgery center, leaving anesthesia providers unsatisfied with pain management of these cases. The project leaders hypothesized that adding an IV magnesium sulfate bolus to the current multimodal analgesic pathway would help increase provider satisfaction with patient care and improve its underutilization among PPMC anesthesia providers.

Do

The project leaders informed anesthesia providers of the new IV magnesium sulfate option to the current pathway for hip arthroscopy patients. While administration of IV magnesium sulfate was not required by anesthesia providers, it was introduced and encouraged as a technique to improve patient care in this surgical population. The project leaders provided a written protocol with details regarding a recommended dosage and duration of IV magnesium sulfate to be given to hip arthroscopy patients.

Study
To determine the effectiveness of this intervention, the project leaders analyzed anesthesia provider satisfaction through the Acceptability of Intervention Measure (AIM) and overall uptake of IV magnesium sulfate by providers.

**Act**

The project leaders reflected on provider satisfaction, uptake of IV magnesium sulfate, barriers to implementation, and strategies to optimize satisfaction with the process of drug administration.

**Theoretical Framework**

The theoretical framework used to support the project purpose and guide clinical decisions for reducing postoperative pain was the Middle-Range Theory of Acute Pain Management. The Middle-Range Theory states that balancing analgesia and reducing the side effects is the optimal goal with analgesic medications (Good, 1998). Balancing this relationship of analgesia and symptom management aligns with the goals of the magnesium study. The Middle-Range Theory applies to our project of treating acute pain with intraoperative magnesium sulfate, with hopes to decrease total narcotic consumption and the undesired side effects caused by opioids. This theory provides a conceptual basis for addressing high postoperative pain scores in hip arthroscopy patients and supports the motive to decrease pain scores using the synergistic effects of IV magnesium sulfate as an adjunct.

**Methods**

**Setting**

The magnesium quality improvement project was implemented at an ambulatory surgical center located in a metropolitan area on the East Coast. This outpatient surgical center is affiliated with a large hospital network with a great reputation for research, teaching, and
healthcare excellence. Services provided at the surgical center included: orthopedics, general surgery, urology, Ear Nose and Throat (ENT), gynecology, plastic, oral, and ocular plastics surgery. Pain management services provided at this outpatient surgery center include nerve blocks and neuraxial anesthesia.

One surgery that typically takes place at this outpatient surgical center is hip arthroscopy. The current analgesic regimen for hip arthroscopy prior to the implementation of this project utilized general anesthesia with a fascia iliaca block for postoperative pain management. Standard induction doses of Fentanyl and Ketorolac before emergence were typically given, unless contraindicated. However, there was no set regimen on intraoperative opioid administration and its use varies among providers and patient-specific needs. PACU orders included as-needed doses of oral oxycodone-acetaminophen and IV fentanyl for moderate to severe pain. The regimen of a fascia iliaca block, ketorolac, and opioid administration were multimodal attempts at treating pain in hip arthroscopy patients. However, anesthesia providers were less liberal in opioid administration due to the ambulatory nature of this facility. This, in addition to an incomplete nerve block, led to high levels of postoperative pain that left anesthesia providers unsatisfied with their anesthetic management of these patients. This project was created to determine the effects of IV magnesium sulfate on anesthesia provider utilization of this non-opioid analgesic adjunct and satisfaction of patient care.

Participants

The participants of the project were anesthesia providers assuming intraoperative care of hip arthroscopy patients operated on by Dr. John Kelly. They were thoroughly informed of the added option of using IV magnesium sulfate for these cases, as discussed in the intervention section. The use of IV magnesium was suggested and encouraged but by no means required. This
allowed later analysis to gauge anesthesia providers’ perceptions of IV magnesium sulfate and potentially create opportunities to refamiliarize them with magnesium’s analgesic properties that benefit patients in opioid-sparing ways. A recommended exclusion criterion was made available for provider reference to assist in the process of making an informed decision that is safe and individualized for the patient. The provider would consider avoiding IV magnesium usage on the following patients:

- Any severe hepatic, cardiovascular, or renal dysfunctions,
- Heart blocks
- Neuromuscular diseases
- Pre-existing coagulopathies
- Known hypermagnesemia
- Patients who are pregnant or breastfeeding
- Currently taking calcium channel blockers, beta-blockers, or antipsychotic medications
- Hypersensitivity to magnesium sulfate

This list was provided to anesthesia staff who wished to consider patients who may not be proper candidates to receive IV magnesium sulfate for analgesia. However, the list was not all-inclusive and it was made clear that it was up to providers to weigh the risks and benefits before administration. The project took place over twelve weeks for a goal of 20 hip arthroscopy cases where IV magnesium sulfate use was appropriate and considered.

**Intervention**

The multi-step intervention was divided into three phases. First, anesthesia providers were reminded of IV magnesium sulfate’s analgesic properties and efficacy as an analgesic
adjunct. A brief information sheet about IV magnesium sulfate with recommended dosages, an inclusion and exclusion criterion, and team contact information was provided electronically to all anesthesia providers at PPMC (figures 1 - 3). Additionally, anesthesia providers were refamiliarized with IV magnesium sulfate’s utilization in multimodal analgesia and introduced to the project during a regularly scheduled weekly staff meeting through video telecommunications. All project team members participated in this session to promote cultural buy-in. Second, nurses at the ambulatory surgery center were introduced to IV magnesium sulfate and its analgesic properties through an in-person presentation of the project at their regularly scheduled staff meeting. Two groups were educated – group one consisted of intraoperative nurses and group two consisted of preoperative and postoperative nurses. Third, the current multimodal analgesic pathway for Dr. John Kelly’s hip arthroscopy patients was modified to include an additional IV magnesium sulfate option for anesthesia provider use. The decision to give IV magnesium sulfate was made by the primary anesthesia team assuming care for the patient that day. Information sheets were placed throughout the facility to remind staff and encourage magnesium’s use, though care was taken not to mandate its administration. An information sheet was posted in every operating room (OR) at the ambulatory surgery center and in the anesthesia office at PPMC.

During project implementation, several project modifications were made to ensure project success. To encourage provider’s participation in the project and to increase the survey compliance, the QI project team sent a reminder email and text to providers assuming care for Dr. John Kelly’s hip arthroscopy patients the night before and morning of respectively. Providers were able to actively communicate with the project leads directly if concerns rose during the implementation of IV magnesium sulfate. Instead of administering a bolus and an infusion of IV
magnesium as outlined in the original proposal, the QI project team decided to recommend
administering a bolus of 30mg/kg with a maximum dose of 2g. The magnesium dosage
modification was made due to a request from anesthesia providers at the project implementation
site, with hopes that implementing a smaller dose of magnesium would avoid any potential side
effects, such as muscle weakness, that may delay discharge. The project leaders also suggested
administering magnesium over a minimum duration of fifteen minutes but up to one hour to
maintain hemodynamic stability and avoid potential adverse effects on blood pressure. The
project team limited the magnesium intervention to the first two hip arthroscopy cases of the day
to avoid delays in discharge from patients potentially experiencing lethargy after receiving
magnesium. Although evidence shows that lethargy after 2g of IV magnesium sulfate
administration is unlikely, this modification was made to ease anesthesia provider concerns and
improve the success rate of the project. To determine the change in magnesium usage before and
after project implementation, project leads performed a retrospective chart review for twelve
weeks before the implementation date and recorded the number of hip arthroscopy cases that
utilized magnesium. Finally, to collect more data, the project team extended our implementation
from eight to twelve weeks.

Project Implementation Plan

Phase I – Inform

Patients undergoing hip arthroscopies prior to this project received general anesthesia and
a fascia iliaca block for postoperative pain control. An IV magnesium sulfate option was added
to the standard multimodal analgesic pathway and introduced to anesthesia providers. The
project team informed anesthesia providers and perioperative staff of this change at weekly
meetings on February 11th, 2021 and February 18th, 2021, respectively. After the meeting, the project team sent project materials such as PowerPoint presentations used in the meetings and QI project summary sheets, which included inclusion and exclusion criterion, magnesium dosing guidelines, and project leads contact information (Figures 1-3). To make it easier for anesthesia providers to participate in the QI project, the project leaders also posted reminder posters in the operating rooms at Penn Medicine University City where the project took place (Figures 1-3). Providers were informed of QI project protocols and the steps necessary to help implement the project. The availability of IV magnesium sulfate was confirmed with the pharmacy department before implementation of the project and anesthesia providers were given instructions on easily obtaining IV magnesium sulfate from the pharmacy.

**Phase II – Intervention**

Patients undergoing hip arthroscopies continued to receive the current multimodal analgesic pathway – general anesthesia and a facia iliaca block. Assuming inclusion criteria, the anesthesia providers who elected to use the new magnesium multimodal analgesic option administered an IV bolus of 30mg/kg or a max dosage of 2g over 30 minutes after induction of general anesthesia. All patients continued to receive a facia iliaca block before emergence. The magnesium intervention is visually displayed within a process flow chart (Figure 4).

**Phase III – Data collection**

After twelve weeks of project implementation, provider satisfaction of patient care was measured using Research Electronic Data Capture (REDCap) survey distributed electronically. Anesthesia providers accessed and completed this survey in one of two ways, either through a
QR code or a link in the emails they received. Usefulness and satisfaction of the magnesium practice change were then determined through analysis of provider surveys. To determine whether the project had an impact on increasing magnesium usage, the project leaders conducted retrospective electronic chart reviews collecting data on the number of Dr. Kelly’s hip arthroscopy cases in which IV magnesium sulfate was used twelve weeks before project implementation and twelve weeks after project implementation.

**Measures**

To evaluate the success of our implementation plan, the project leaders measured anesthesia provider’s overall uptake of magnesium sulfate use in the perioperative setting, and satisfaction of patient care via an electronic survey. To assess provider’s satisfaction with the addition of the magnesium option, the project leaders used the AIM developed by Weiner et al. (2017). AIM is a four-item measurement of implementation outcomes that is used to assess the stakeholder's acceptability of an implementation (Figure 5). AIM asked anesthesia providers to rate each of the following four items on a 1 to 5 scale. The Response Scale was identified as: 1 = Completely disagree; 2 = Somewhat disagree; 3 = Neither agree nor disagree; 4 = Somewhat agree; and 5 = Completely agree.

1. The IV magnesium option meets my approval.
2. The IV magnesium option is appealing to me.
3. I like the IV magnesium option.
4. I welcome the IV magnesium option.

All anesthesia providers who provided intraoperative care for Dr. Kelly’s hip arthroscopy procedures were given these surveys to assess changes in provider satisfaction upon introducing
the magnesium option to the standard multimodal analgesic pathway (Figure 5). Follow-up
emails were sent weekly to ensure a high response rate.

The project leaders also conducted an electronic chart review on Dr. Kelly’s hip
arthroscopy patients, twelve weeks before and twelve weeks after the project implementation
date. The data recorded included the date of the case and whether magnesium was used. A run
chart displaying the overall trend in magnesium usage pre-intervention and post-intervention
weekly was plotted and analyzed.

**Data Management Plan**

Data was collected and managed using REDCap. REDCap is a software application for
secure data management and collection. To ensure data security, data collected to analyze
magnesium use was un-identifiable and was conducted via retrospective chart reviews. Data
collected to determine anesthesia provider satisfaction was distributed via a REDCap survey and
remained identifiable. Access to REDCap project data was granted only to the project team (Dr.
Ignacio Badiola, Julianne Bagley, Naomi Song, and Erica Yi). The data collected will remain in
the REDCap application to ensure secure long-term storage.

In preparation for data analysis, several strategies were employed to ensure the efficiency
and accuracy of data collection. First, a project log was created within Basecamp, a project
management system, to document problems that arose and decisions that were made. Project
leaders tracked responses and ensured accurate project implementation weekly via Basecamp. A
data codebook was created to include the label for each data item and the level of measurement.
Efficient and accurate data collection was possible through open and documented
communication, frequent project participant monitoring, and a clean data codebook.
Analysis

After project implementation was completed, the data was cleaned to prepare for analysis. Missing responses to questions were removed prior to analysis. The cleaned data was analyzed using descriptive statistics. Absolute frequencies (counts) and relative frequencies (percentages) were used to summarize provider satisfaction with the added option of IV magnesium sulfate to the multimodal analgesic pathway. To assess the relationship between adding IV magnesium sulfate to the multimodal pathway (the independent variable) and actual utilization of IV magnesium sulfate by anesthesia providers, a run-chart was created. Pre- and post-implementation rates of magnesium use for hip arthroscopy patients were determined and plotted on a line graph. Clinical significance was defined as a 50% increase in IV magnesium sulfate administration in this patient population.

Ethical Considerations

This project was acknowledged as a quality improvement initiative by the International Review Board (IRB) of the University of Pennsylvania. There are no financial disclosures.

Results

Over the twelve weeks of implementation phase, ten CRNAs were involved in the anesthetic care of fourteen hip arthroscopy cases by Dr. Kelly and eight CRNAs (respondents) participated in the project survey. Among the two non-respondents, one CRNA opted for the magnesium option but did not respond to the survey while one did not use magnesium at all. A satisfaction survey was not filled out by this provider and no insights were gained as to why the option was not used.

In the AIM survey, 71% (5/7) CRNAs rated at least somewhat agree to “IV magnesium sulfate meets my approval”, and one participating CRNA left this item blank. A total of 75%
(6/8) CRNAs rated at least somewhat agree to “the IV magnesium option is appealing to me”. 75% (6/8) rated at least somewhat agree to “I like the IV magnesium option” and 75% (6/8) rated at least somewhat agree to “I welcome the IV magnesium option (Figure 6a).

100% of participating CRNAs (8/8) reported that their decision to use magnesium was influenced by the QI initiative and would consider using IV magnesium in future practice (Figure 6b). Seven out of seven CRNAs (100%) were satisfied with the QI initiative, and one CRNA left this question blank (Figure 6b).

Comments made by the participating CRNAs regarding their observations of the intraoperative magnesium use on patient care included “smooth emergence” and “patient woke up very comfortable”. Two CRNAs noted “no changes”.

Twelve weeks prior to project implementation, zero out of eighteen hip arthroscopy patients received IV magnesium. With project implementation, twelve out of the fourteen hip arthroscopy patients over a twelve-week period received IV magnesium, yielding an 85.7% increase in IV magnesium utilization. A run chart displaying biweekly rates of IV magnesium utilization before and after this QI initiative was plotted (Figure 7).

Discussion

Summary of Findings

After project implementation, there was an 85.7% increase in IV magnesium utilization for eligible hip arthroscopy patients. Nine out of ten (90%) CRNAs who took care of hip arthroscopy patients used IV magnesium sulfate over a twelve-week project implementation period. 100% of survey respondents reported being satisfied with patient care after incorporating IV magnesium sulfate to their anesthetic plan and would consider using it in future practice.
**Interpretation of Project Results**

IV magnesium sulfate had the potential to mitigate the problem of high pain levels but was found to be scarcely used among anesthesia providers at this institution. By adding IV magnesium sulfate as an optional adjunct to the current multimodal analgesic pathway for hip arthroscopy patients, the project leaders hoped to increase IV magnesium sulfate usage in the perioperative setting and anesthesia provider satisfaction of patient care at PPMC.

The 85.7% increase in magnesium sulfate utilization post-implementation suggested effectiveness of this QI initiative in increasing magnesium usage at PPMC. In fact, 100% of CRNAs that responded to the project survey stated that they would consider using IV magnesium in their future practice. This project helped demonstrate that IV magnesium sulfate is a readily available and appropriate non-opioid analgesic adjunct for surgical patients.

During weeks 5 and 6 of project implementation, there were no hip arthroscopy cases performed at the ambulatory surgery center. IV magnesium sulfate use dropped to 0% as a result of the lack of opportunity for utilization (Figure 6a). Therefore, the steep decline in IV magnesium utilization during these weeks was not clinically significant.

The project team found overall positive responses to IV magnesium sulfate and its implication on patient care. Many anesthesia providers were willing to consider its use in future practice, apart from this project initiative. Increased utilization of IV magnesium sulfate has multifactorial benefits. IV magnesium is less costly than opioids, which decreases costs to the patient and hospital. The anesthesia provider’s challenge in achieving adequate analgesia is addressed by the non-opioid properties of IV magnesium. Use of IV magnesium through this project initiative may inspire these CRNAs to administer magnesium in other settings where they provide anesthetic care and help promote its use among the anesthesia community at PPMC.
Limitations

Several limitations should be considered when interpreting the results of this project. The number of hip arthroscopy cases at the ambulatory surgery center was far less than expected. The limited number of participants could be due to a smaller volume of surgical cases performed during the COVID-19 pandemic. As a result, the project leaders cannot exclude the possibility of false statistical significance. Finally, the limited nature of interpersonal interaction and challenges of virtual meetings during the pandemic could have negatively impacted cultural buy-in.

Conclusion

It was found that patients undergoing hip arthroscopy at PMUC experienced high levels of postoperative pain. IV magnesium sulfate has been shown to be an effective analgesic adjunct that could help decrease postoperative pain without the adverse effects seen with opioid administration. An organizational assessment and analysis of CRNA experiences in anesthetic practice led to this QI initiative. The addition of IV magnesium sulfate to the current multimodal analgesic pathway for Dr. Kelly’s hip arthroscopy patients resulted in an increase of 85.7% in IV magnesium. 100% of anesthesia providers who administered IV magnesium were satisfied with patient care as a result of this project implementation. The goal of increasing IV magnesium use as a non-opioid analgesic adjunct among anesthesia providers and improving patient care satisfaction was achieved.

Sustainability Plan

After project implementation, conclusion, and dissemination of the results, the successes and failures of the project were evaluated using the PDSA framework and the Middle-Range Theory of Acute Pain Management.
The analgesic effects of magnesium are high yield for the patient, the anesthesia provider, and the hospital. Magnesium is an abundant and inexpensive medication that has shown great success in decreasing pain scores and opioid consumption, which leads to improved patient and provider satisfaction. Magnesium is not only easy for providers to use, but also inflicts fewer side effects that would be seen with opioid use. Magnesium's intraoperative use is likely to be sustained after project termination. Open communication with key stakeholders about the project is important for long-term sustainability and therefore a reassessment of buy-in from key stakeholders is necessary. Project results were shared with key stakeholders. Through proper evaluation of the project and maintenance of open communication, the utilization of magnesium sulfate as an analgesic adjunct will likely increase. Communication with stakeholders will take place on-site or through virtual platforms depending on the trajectory of COVID-19 and evolving changes to Centers for Disease Control and Prevention (CDC) guidelines.

**Implications for Practice**

Magnesium is widely used in anesthesia practice as a multimodal analgesic but is infrequently utilized at Penn Presbyterian Medical Center. The multimodal analgesic pathway for hip arthroscopy patients did not incorporate magnesium sulfate prior to the implementation of this project. This quality improvement project incorporated the latest evidence and addressed the gap in magnesium utilization by refamiliarizing anesthesia providers with magnesium’s analgesic properties. Re-introducing anesthesia staff to the analgesic components of IV magnesium sulfate creates a culture that utilizes magnesium readily and appropriately as a non-opioid analgesic adjunct. This project targeted a specific population, but the intervention of an IV magnesium sulfate bolus is easily transferrable to various surgical procedures. It is our hope that this project helped incorporate IV magnesium sulfate as an analgesic adjunct for anesthesia
providers to consider in their daily anesthetic practice. Experiencing the effectiveness of IV magnesium sulfate widens the range of analgesic options available to anesthesia providers and facilitates practice change with beneficial outcomes.

References


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https://doi.org/10.1016/j.aat.2016.06.003

bilateral total knee arthroplasty: A randomized, double-blinded, placebo-controlled trial. 


[https://doi.org/10.1097/EJA.0000000000000641](https://doi.org/10.1097/EJA.0000000000000641)


[https://doi.org/10.1155/2015/306145](https://doi.org/10.1155/2015/306145)


[http://doi.org/10.1186/s13012-017-0635-3](http://doi.org/10.1186/s13012-017-0635-3)
MAGNESIUM UTILIZATION IN HIP ARTHROSCOPY

Figures

Figure 1

Quality Improvement Project Summary Sheet - 1

Does the addition of IV magnesium sulfate to a multimodal analgesic pathway improve its utilization and anesthesia provider satisfaction for hip arthroscopy patients at PMUC?

Inclusion Criteria

- Hip arthroscopy patients
- By Dr. John Kelly
- Ambulatory Surgery Center
- ASA I & II
- >18 years old
- First two cases of the day

Exclusion Criteria

- CV disease
- Coagulopathy
- Beta blocker use
- Antipsychotic use
- Renal dysfunction
- Severe hepatic disease
- Neuromuscular disease
- Hx or current heart block
- Ca2+ channel blocker use
- Pregnant or breastfeeding
- Known hypersensitivity to Mg

Intraoperative Dosing Guidelines

Bolus: 30 mg/kg over 15 minutes
Max dose of 2g

Infusion terminated by emergence of anesthesia. Patients will continue to receive general anesthesia with a fascia iliaca block, the current multimodal analgesic pathway.

Questions?

Dr. Ignacio Badiola / 305 987 3382
Ignacio.Badiola@pennmedicine.upenn.edu

Julianne Bagley / 215 290 0668
Naomi Song / 207 577 3286
Erica Yi / 718 451 6289
Figure 2

Quality Improvement Project Summary Sheet – 2

Figure 3

Quality Improvement Project Summary Sheet – 3
Figure 4

Process Flow Chart
Note. Anesthetic management with QI initiative option added to the multimodal pain pathway for Dr. Kelly’s hip arthroscopy patients at Penn Medicine University City Ambulatory Surgery Center.

Figure 5

AIM Survey & Satisfaction Survey

Rate each of the following four items on a 1 to 5 scale.
Note. Post-implementation magnesium survey distributed to anesthesia providers to assess satisfaction with patient care using AIM (questions 1-4) and magnesium use.

Figure 6

6a. AIM Survey Results
Note. AIM Survey and Satisfaction Results display the frequencies of each magnesium satisfaction score from anesthesia providers.

6b. Magnesium Uptake, Future usage and Satisfaction

Was your decision to use magnesium for this case influenced by the updated multimodal analgesic pathway highlighted by this quality improvement project?

<table>
<thead>
<tr>
<th>Total Count (N)</th>
<th>Missing</th>
<th>Unique</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>2.00%</td>
<td>1</td>
</tr>
</tbody>
</table>

Counts/frequency: Yes (8, 100.0%), No (0, 0.0%)

Would you consider using IV magnesium in your practice in the future?

<table>
<thead>
<tr>
<th>Total Count (N)</th>
<th>Missing</th>
<th>Unique</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2.00%</td>
<td>1</td>
</tr>
</tbody>
</table>

Counts/frequency: Yes (7, 100.0%), No (0, 0.0%)
Figure 7

_Magnesium Use Run Chart_

*Note.* Rate of IV magnesium sulfate usage by anesthesia providers over 8 weeks pre-implementation and 12 weeks post-implementation.
**Table 1**

*Synthesized Table of Evidence*

<table>
<thead>
<tr>
<th>Citation</th>
<th>Surgical Sample</th>
<th>Anesthetic, ASA class</th>
<th>Intra-op Magnesium Treatment</th>
<th>Sample Size (n)</th>
<th>Post-op evaluation time (t)</th>
<th>Post-op Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dehkordy et al., 2020</td>
<td>Posterior lumbar surgery</td>
<td>GA, ASA 1-2</td>
<td>+</td>
<td>N = 120</td>
<td>48 hours</td>
<td>↓ pain scores ↓ analgesic requirements</td>
</tr>
<tr>
<td>El Mourad et al., 2020</td>
<td>Lap. Sleeve gastrectomy</td>
<td>GA, ASA 1-2</td>
<td>+</td>
<td>N = 120</td>
<td>24 hours</td>
<td>+</td>
</tr>
<tr>
<td>Gucyetmez et al., 2016</td>
<td>Liver Transplant</td>
<td>GA</td>
<td>+</td>
<td>N = 70</td>
<td>24 hours</td>
<td>+</td>
</tr>
<tr>
<td>Jarahzadeh et al., 2016</td>
<td>TAH</td>
<td>GA, ASA 1-2</td>
<td>+</td>
<td>N = 60</td>
<td>12 hours</td>
<td>+</td>
</tr>
<tr>
<td>Mireskandar i et al., 2015</td>
<td>Cesarean Section</td>
<td>GA, ASA 1-2</td>
<td>+</td>
<td>N = 50</td>
<td>24 hours</td>
<td>+</td>
</tr>
<tr>
<td>Sahar et al., 2017</td>
<td>Arthroscopic knee</td>
<td>Epidural, ASA 1-2</td>
<td>+</td>
<td>N = 70</td>
<td>24 hours</td>
<td>+</td>
</tr>
<tr>
<td>Shah et al., 2016</td>
<td>Lower abdominal/lower limb surgery</td>
<td>Spinal, ASA 1-2</td>
<td>+</td>
<td>N = 108</td>
<td>24 hours</td>
<td>+</td>
</tr>
<tr>
<td>Shin et al., 2016</td>
<td>TKA</td>
<td>Spinal, ASA 1-2</td>
<td>+</td>
<td>N = 44</td>
<td>48 hours</td>
<td>+</td>
</tr>
<tr>
<td>Sohn et al., 2017</td>
<td>VATS</td>
<td>GA</td>
<td>+</td>
<td>N = 66</td>
<td>48 hours</td>
<td>+</td>
</tr>
</tbody>
</table>
Note: IV magnesium sulfate bolus and/or infusion given in various surgical procedures show a decrease in postoperative pain scores and analgesic requirements twenty-four to forty-eight hours after.

ASA = American Society of Anesthesiologist; GA = General Anesthesia; TAH = Total Abdominal Hysterectomy; TKA = Total Knee Arthroplasty; VATS = Video-Assisted Thoracoscopic Surgery.

Table 2

<table>
<thead>
<tr>
<th>Citation or Study No.</th>
<th>Research Aim, Question, Hypothesis</th>
<th>Setting, Sample, and Sampling</th>
<th>Design</th>
<th>Variables and Measures</th>
<th>Findings</th>
<th>Critique</th>
<th>Level of Evidence</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dehkordy et al., 2020</td>
<td>This study hypothesized that magnesium sulfate administration will reduce postoperative pain.</td>
<td>Randomized double-blind parallel-controlled clinical trial conducted in Shohada Tajrish training hospital in 2018-2019. 120 patients assessed for eligibility</td>
<td>Pts were randomly divided into 2 groups. Exposure was 50mg/kg bolus of magnesium sulfate in 100mL saline over 15 min prior to induction, followed</td>
<td>Control: 50mg/kg bolus of isotonic saline followed by continuous 15mg/kg/h infusion during operation. Experiment al: 50mg/kg bolus of</td>
<td>Significant: PCA morphine consumption at 6, 12, 24, 48 hrs postoperatively lower in magnesium group; lower rate of rescue analgesic request from</td>
<td>Strengths: Large sample size RCT study design</td>
<td>1B</td>
<td>Perioperative IV magnesium administration improves postoperative analgesia, decreases morphine consumption.</td>
</tr>
</tbody>
</table>

Weaknesses: Literature showed varying results. No clear conclusion based on paucity of data.
El Mourad et al., 2020
Study hypothesized that IV or IP magnesium sulphate will reduce the hemodynamic stress response to pneumoperitoneum and provide improved pain control after Randomized controlled double-blind study from January-May 2018. N=120 aged 18-60 years with BMI>35 kg/m2 and ASA I-II enrolled. 3 groups (n=40 each). Exposure was either 100mL 30mg/kg IV MgSO4 or 30mL of IP MgSO4.

Control: Group C: 100mL of 0.9% NS over 10min with 30mL NS IP

Experiment: Group I: 100mL of 30mg/kg MgSO4 with IP instillation

Significant: MAP and HR lower from T3 to T8 in group I > P > C. Pain scores highest in group C > I > P 2hrs postoperatively.

Lower VAS score in group P, no significant difference from group I. Strengths: RCT study design. Large sample size. Ease of replicability. Weaknesses: Scarce data on magnesium dosing in obese patients. Reputability and

Magnesium utilization in hip arthroscopy

(20-80 years old) ASA 1-2 who underwent posterior lumbar surgery. After exclusion, N=80 for randomization. Sample size was divided into two (n=40) groups. Magnesium sulfate over 15 min prior to induction, followed by continuous 15mg/kg/h infusion during operation. VAS assessed prior to and post operation. Non-significant: Intraoperative blood loss.

data and controversial conclusions from systematic reviews.
of 30mL of 0.9% NS

Group P:
100mL
0.9% NS
over 10 min
with 30mL
of 30mg/kg
IP MgSO4

difference
to between
group C and
I (P=0.070).

Nonsignificant:
No variation
in VAS
score
amongst all
groups at 8,
12, 24h
postoperativ
eperiod up
to 4 hours in
obese
patients
undergoing
LSG.

The study hypothesized IV MgSO4 reduces postoperative tramadol requirement in liver transplant patients.

Randomized double blind, N=70 from October 2014 to April 2015, age > 18yrs old with operation duration of 10-12hrs and clamping duration of

N=70 divided into two groups (experimental group with baseline serum mag <1.8; and control group baseline serum mag >1.8). Exposure

Experiment al: 50mg/kg IV MgSO4 in the last 30min of surgery.

Control: same volume of NS.

Measure:
Patient's age, sex,

Significant:
the magnesium group had lower mean 24-hr total tramadol requirement, duration of MV and longer 1st tramadol timing (P<0.001)

Strength:
Findings in this study are consistent with other studies; project leaders also divided up the groups by its baseline serum magnesium

Gucyetmez et al., 2016

Intraoperative use of IV MgSO4 in liver transplant patients reduces the need for postoperative tramadol and MV.
<p>| Published in | Study hypothesis | Magnesium sulphate administration will reduce postoperative pain and narcotic requirement after abdominal hysterectomies. | Double-blind, randomized clinical trial in Shahid Sadoughi Hospital in Iran from 2013 to 2015 with N=60. Pts age 35-65 years old, ASA I-II. | Two groups of n=30 each. Exposure was 50mg/kg magnesium sulfate in 500cm³ of Ringer's serum over 20 minutes. | All groups received 5mg morphine 30min after induction of anesthesia. | Significant: Pain scores lower in experimental group at all time intervals up to 6hrs after surgery. Control group required more rescue opioids. | Non-significant: age, sex, BMI, operation duration, MELD, APACHE II. LOS-ICU, LOS-hospital were comparable level that made the effect of magnesium more significant between two groups. | Weakness: small sample size | Strengths: High level of study design. | Weakness: No differentiation in BSA was accounted for when administering narcotics. All patients received the same dosage of midazolam | 50mg/kg intraoperative IV magnesium sulfate administration significantly decreases postoperative pain and reduces morphine consumption after abdominal hysterectomy. |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>Hypothesis</th>
<th>Design</th>
<th>Participants</th>
<th>Intervention</th>
<th>Outcome</th>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mireskandari et al., 2015</td>
<td>IV MgSO4 decrease post-caesarean pain and opioid requirement during first 24 hours.</td>
<td>Double blind randomized clinical trial occurred at Tehran University of Medical Sciences. N=50, ASA I and II scheduled for elective C/S</td>
<td>N=50 divided up to two groups. Exposure in the experimental group was 50mg/kg IV MgSO4 infused within 15min prior general anesthesia</td>
<td>Experiment: 50mg/kg IV MgSO4 made in 500ml NS infused within 15min prior general anesthesia</td>
<td>Significant: mag group has lower VAS scores at 1, 6, 12th hours after c/s (p&lt;0.001, 0.002, 0.05 respectively), and lower morphine usage during 24hours (p&lt;0.001)</td>
<td>High level of study design, and relate findings to other similar studies</td>
<td>Small sample size</td>
</tr>
</tbody>
</table>

Serum VAS scores were assessed in the immediate postoperative period, then at 1, 2, 6, and 12 hours after surgery.

Small sample size and rather narrow age range for inclusion criteria was utilized without explanation.

MgSO4 administration immediately prior to induction of general anesthesia decrease VAS score, as well as postop morphine requirement during the first 24hours.
| Sahar et al., 2017 | This study hypothesized IV MgSO4 infusion attenuate TIH and tourniquet pain and also reduce postop analgesia requirement in patients undergoing arthroscopic knee surgery under epidural anesthesia. | Randomized, double blind controlled study, N=70, ASA I and II (age 20-60 years) undergoing arthroscopic knee surgery with tourniquet under epidural anesthesia. N=70, n=35. Exposure was IV MgSO4 bolus 30mg/kg in 50ml NS over 10min, followed by infusion 10mg/kg/h. IV fentanyl was given if needed. | Experiment: IV MgSO4 bolus 30mg/kg in 50ml NS over 10min, followed by infusion 10mg/kg/h. Control: same volume of NS for bolus and infusion. | Significant: patients in the experimental group had lower SBP, DBP, HR (p<0.001) after 50min of inflation, less TIH and lower VAS score for tourniquet pain (p<0.05), longer time to feel pain (p<0.001), lower intraoperative fentanyl requirement (p<0.001), with higher serum mag level at 6h | Strength: The study was clear on their inclusion and exclusion criteria and project leaders used multiple measures at multiple time points when analyzing the effect of magnesium on pain and its intraoperative benefits | Weakness: VAS was not assessed with movement | Strength: 1B | In patients undergoing arthroscopic knee surgery under epidural anesthesia, IV MgSO4 in a dose of 30 mg/kg, followed by 10 mg/kg/h infused before tourniquet inflation could reduce TIH, and tourniquet pain with reduction in intraoperative IV fentanyl and postoperative pethidine |
| Shah et al., 2016 | The hypothesis of the RCT is the increase of analgesic | Prospective randomized control trial, double-blinded study with Two groups of n = 54 each. The exposure was a magnesium Experiment | 250 mg magnesium bolus followed by 20mL/hr infusion | Strengths: large sample size and generalizability to adult patients | Strengths: statistically significant: VAS scores immediately post-op (p = 0.006) and sample size was small | Requirement: small sample size was required. |
effects and duration of sensory/motor blockade of I.V. magnesium during spinal anesthesia. Study also analyzed hemodynamic effects of magnesium and the analgesic requirements after surgery.

N = 108 patients undergoing lower abdominal and lower limb surgery with spinal anesthesia. ASA I and II, 18-65 years of age, and height within 150-180 cm.

A bolus of 250mg IV followed by an infusion of 20mL/hr of magnesium.

Control group: received the same volume as magnesium group, but with normal saline.

Post-op pain assessed with VAS, rating pain 1-10. Rescue analgesia given when pain score above 3. Sensory blockade time recorded when sensory block regression

at the 4-hour interval (p = 0.001) decreased in the experimental group. Sensory blockade increased about 25 minutes and motor blockade increase of about 34 minutes in experimental group (p = 0.001).

Number of rescue analgesic requirements decreased in the experimental group (p = 0.009)

undergoing surgery with spinal anesthesia. Weaknesses: no differentiation of analgesic requirements, sensory blockade, and motor blockade between magnesium group and longer spinal blockade.

Significantly decreases VAS scores immediately post-op and within 4 hours, increases sensory and motor blockade, and decreases post-op rescue analgesic requirements.
| Study hypothesized magnesium can reduce post-op pain scores and intensity for patients undergoing the second of a staged bilateral TKA, occurring one week after the first surgery. | Randomized double blinded control trial. Conducted at Seol National University Bundang Hospital from March to December 2015. N = 44 patients undergoing staged bilateral TKA under all patients received pre-op Midazolam, femoral nerve block, and spinal anesthesia. Experiment al group: received 50mg/kg of magnesium over 15 minutes, followed by infusion of 15mg/kg/hr for the remainder of the surgery. All patients received pre-op Midazolam, femoral nerve block, and spinal anesthesia. | Statistically significant: VAS scores higher in control group compared to experimenta l group after the first TKA (p = 0.001) and after the second TKA (p < 0.001). In the control group VAS scores were statistically higher than in the experimenta l group. | Strengths: high level of study design (double blinded RCT) and the reproducibility of the study described. | Weaknesses: majority of the study population were elderly females. | Magnesium successfully decreased VAS scores and analgesic requirement s despite an increase in pain intensity with the second surgery of a staged bilateral TKA. Magnesium may be
spinal anesthesia, ages 50-80 years, and ASA I and II.

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>For the remainder of the surgery.</td>
<td>Pain determined by VAS score instead of quantitative sensory testing (QST). Pain only assessed at rest because of increased pain intensity with mobilization.</td>
</tr>
<tr>
<td>Control group: received the same volume as the experimental group, but in isotonic solution.</td>
<td>Pain only assessed at rest because of increased pain intensity with mobilization.</td>
</tr>
</tbody>
</table>
| VAS used to assess post-op pain scores ranging from 0-100 at the 24 and 48 hour time interval. | Non-significant: In the experimental group VAS scores did not increase significantly between the first TKA and the second at 24 hours (p = 0.480) and 48 hours (p = 0.006).
| Rescue analgesic and PCA use assessed at the 24 and 48 hour time intervals. | Effectiveness at controlling increased pain caused by multiple surgeries with increased intensity. May decrease chronic pain due to its effects to decrease post-op analgesic requirements. |

Increased at 24 hours (p = <0.001) and 48 hours (p = 0.011) post-op and PCA requirements increased after the second TKA surgery compared to the first (p = 0.004).
<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Design</th>
<th>Randomized double-blind occurred in a university tertiary care center, N=66, 25-75 years old, thoracoscopic surgery of segmentectomy or lobectomy, tracheal extubation in the OR, and postop pain management using PCA.</th>
<th>N=66 divided into 2 groups. Exposure was IV Mag 50mg/kg for 10 min followed by a continuous infusion of 15mg/kg/hr during surgery</th>
<th>Statistical significant: FEV1 and FVC are greater in the magnesium group postop 24 and 48 hours. Mag group required less rocuronium, and lower PCA consumptio n.</th>
<th>Strength: RCT design</th>
<th>Weakness: small sample size, and project leaders did not measure mag concentratio n postoperativ ely, which could affected the post analgesia needs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sohn et al., 2017</td>
<td>This study hypothesized IV MgSO4 help improve PFT results, reduce muscle relaxant requirement, and PCA requirement after video-assisted thoracoscopic surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Taheri et al., 2015       | The study hypothesized a single bolus of IV MgSO4                           | Double blinded, randomized placebo. Two groups of n= 20 each. The exposure Experiment al group: received a 50mg/kg in
 |                                                                                          | time intervals. Experiment al: IV Mag 50mg/kg for 10 min followed by a continuous infusion of 15mg/kg/hr
 |                                                                                          | Control: same volume of NS bolus and infusion. Measure: PFT: at preop, postop at 2, 24, and 48h; total usage of muscle relaxant; total PCA consumptio n |
|                           |                                                                                          |                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

1B Intraoperative IV MgSO4 improved PFT and reduced the need for muscle relaxant and PCA requirement under video assisted thoracoscopic surgery.
Magnesium sulfate will lower post-op pain scores following a TAH under general anesthesia. Study took place at the OBGYN ward at Al-Zahra Maternity Hospital in Rasht from May 2013 to May 2014. N = 40 women having a TAH with general anesthesia, ASA I or II. Magnesium sulfate bolus 50mg/kg was a 100mL bolus of magnesium sulfate 15 minutes prior to induction. Control group: received an 100 mL of NS. Demerol consumption and NRS evaluated at 0, 6, 12, and 24 hour time intervals post-op. Lower in the experimental group at the 6, 12, and 24 hour time interval after surgery (p<0.05). Demerol requirement was lower in the experimental group throughout the whole 24 hour post-op period (p = 0.0001). Non-significant: post-op pain scores at the time of emergence. Lowering pain scores at 6, 12, and 24 hour post-op and decreasing opioid consumption in patients undergoing general anesthesia.

**Note:** Level of evidence of ten studies evaluating IV magnesium sulfate.

| APACHE | = Acute Physiology and Chronic Health Evaluation | ASA | = American Society of Anesthesiologist | BMI | = body mass index | C/S | = cesarean section | IP | = Intraperitoneal | IV | = Intravenous | LOS-hospital | = length of hospital stay | LOS-ICU | = length of intensive care unit stay | MELD | = Model for End-Stage Liver Disease | MgSO4 | = Magnesium Sulfate | MV | = duration of mechanical ventilation | NRS | = Numeric Rating Scale | NS | = Normal Saline | PFT | = pulmonary function test | PONV | = postoperative nausea and vomiting |
vomiting; TAH = Total Abdominal Hysterectomy; TIH = tourniquet induced hypertension; TKA = Total Knee Arthroplasty; VAS = Visual Analog Scale.
Appendix A

DNP Team and Project Implementation Form

University of Pennsylvania
School of Nursing
Doctor of Nursing Practice Program

DNP Team and Project Implementation Form

Student Name(s): Julianne Bagley, Naomi Song, Erica Yi

Project Topic/Title: Intraoperative Administration of Intravenous Magnesium Sulfate to Reduce Postoperative Pain in Hip Arthroscopy Patients

UPENN School of Nursing DNP Project Lead: Dr. Holly Brogan

Institutional/Organizational DNP Project Member(s): Dr. Ignazio Badiola (Site Lead), Dr. Nabil Elkassabasy Dr. John Kelly

I hereby accept the following proposed project pending IRB approval (completed by student(s))

Research Site(s):

Penn Presbyterian Medical Center / Ambulatory Surgery Center

Study/Project Purpose: To reduce postoperative pain in hip arthroscopy patients

Study Activities: Bolas and continuous infusion of IV magnesium sulfate on a weight-based dose, given intraoperatively

Subject Enrollment: Hip arthroscopy patients receiving fascia iliaca blocks
Site(s) Support: Dr. Ignacio Badiola, Anesthesia Department, Pharmacy, PACU department

Data Management: RedCap

Anticipated End Date: March 2021

University of Pennsylvania
School of Nursing
Doctor of Nursing Practice Program

DNP Team and Project Implementation Form

I hereby consent to serve on [ ] Text [ ] DNP project committee

E-mail address of doctoral student(s): bagleyj@upenn.edu, nsong@upenn.edu, yierica@upenn.edu

We understand that this site’s participation will only take place during the project’s active IRB approval period. All study activities must cease if IRB approval expires or is suspended. We understand that any activities involving Personal Private Information of Protected Health Information may require compliance with HIPAA Laws and The University of Pennsylvania’s Policy. Our organization agrees to the terms and conditions stated above. If we have any concerns related to this project, we will contact the project team. For concerns regarding IRB policy or human subject welfare, we may also contact the UPENN IRB.

As a doctoral student member of this team, I agree to conduct the project to the best of my abilities with professionalism.

Student(s) signature(s): [Signature]

As an institutional/organization member of this project team, I agree to read and review all drafts of the project within a timely turnaround (approx. 2 weeks)

Institutional/Organizational Project Member(s) signature(s): [Signature]
As the School of Nursing DNP Project Lead, I agree to meet with the student(s) and consult throughout the project.

Email address/Phone:  

SON DNP Project Lead Signature  

Email address/Phone: Hollylb@upenn.edu  

APPROVED:  

[Director, Doctor of Nursing Practice Program]  

Date
Appendix B

Project Charter

AIM

Magnesium sulfate is inconsistently utilized for multimodal analgesia at Penn Presbyterian Medical Center (PPMC). By adding the option to include IV magnesium sulfate to the current multimodal analgesic pathway for hip arthroscopy patients, the project leaders hope to inspire practice change of increasing magnesium sulfate use. The purpose of our quality improvement project is to inform and refamiliarize anesthesia providers with magnesium sulfate's multimodal analgesic properties, and to increase IV magnesium sulfate use in the perioperative setting and provider satisfaction of patient care.

PROBLEM

Hip arthroscopy patients experience high levels of postoperative pain, leading to higher pain scores, increased rescue analgesic consumption, and decreased patient satisfaction. Magnesium sulfate is widely used in anesthesia practice as a multimodal analgesic but is underutilized at Penn Presbyterian Medical Center. Does adding the option of IV magnesium sulfate to the current multimodal analgesic pathway increase magnesium use and provider satisfaction of patient care?

IMPORTANCE

Magnesium has demonstrated to be an effective multimodal analgesic agent and is a low-cost agent but is infrequently utilized at PPMC. This magnesium quality improvement project serves as a re-introduction to the PPMC anesthesia staff to the possibilities of IV magnesium sulfate as an analgesic adjunct for many surgical procedures and create a culture that utilizes magnesium readily and appropriately as a non-opioid analgesic adjunct. If magnesium is used effectively, it can facilitate practice change among anesthesia providers regarding analgesic options for patient care.

EXPECTED OUTCOMES

For anesthesia providers taking care of patients undergoing hip arthroscopy operated on by Dr. John Kelly at the Ambulatory Surgery Center in University City. A target of 20 anesthesia providers will be met in a 12-week implementation phase.

1. 50% will receive a bolus and continuous infusion of IV magnesium sulfate on a weight-based dose.
2. 50% anesthesia providers express satisfaction on patient care after adding magnesium to the current analgesic pathway
3. 50% anesthesia provider accepts this practice change and will consider magnesium in future practice

MEASURES
A REDCap survey will be distributed electronically to assess anesthesia provider’s overall uptake of IV magnesium administration in the new multimodal analgesic pathway, as well as satisfaction on patient care. The Acceptability of Intervention Measure (AIM) will ask anesthesia providers to rate each of the following four items on a 1 to 5 scale. The Response Scale will be identified as: 1 = Completely disagree; 2 = Somewhat disagree; 3 = Neither agree nor disagree; 4 = Somewhat agree; and 5 = Completely agree.

1. The IV magnesium option meets my approval.
2. The IV magnesium option is appealing to me.
3. I like the IV magnesium option.
4. I welcome the IV magnesium option.

Additional questions will be added to AIM to assess provider’s overall uptake on magnesium use after our implementation.

1. Have you consistently used IV magnesium as an analgesic adjunct in your anesthetic practice previously? Yes or no
2. Did you use magnesium for this case? Yes or no
3. Was your decision to use magnesium for this case influenced by the updated multimodal analgesic pathway highlighted by this quality improvement project? Yes or no, I have always considered magnesium in my practice.
4. Are you likely to consider using IV magnesium in your practice in the future? Yes or no
5. Are you satisfied with your patient care as a result of this QI initiative? Yes or no.

RISKS/BARRIERS

While research has displayed magnesium to be an effective analgesic adjunct, the project site inconsistently utilizes magnesium currently as an analgesic adjunct. Staff buy-in is a potential barrier to success of the magnesium quality improvement project.

STAKEHOLDERS

The stakeholders of this project will be Dr. Mark Pizzini (Director of Anesthesia), Edward Czerpak (Chief CRNA), Dr. Ignacio Badiola (Site Lead), pharmacists, CRNAs and PACU nursing team at the project site. Successful implementation of the project will require buy-in from key stakeholders, and therefore information on the purpose and detailed intervention measure will be distributed among the key stakeholders and issues and concerns will be followed up by the project leads via email and in-person interaction, as allowed, on a weekly basis. Patient improvement will be analyzed through weekly chart reviews of pain scores and opioid consumption to ensure the patient experience is satisfactory.

SCOPE

<table>
<thead>
<tr>
<th>In Scope:</th>
<th>Out of Scope:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anesthesia providers providing care for patients who are age &gt;18 years, ASA I-II, patients undergoing hip arthroscopy procedures with general anesthesia and fascia iliaca block, operated on by Dr. John Kelly</td>
<td>Anesthesia providers who are not participating in anesthetic management and patient care for these case types.</td>
</tr>
</tbody>
</table>

SCHEDULE
Project implementation will begin in February 2021 for 12 weeks.

<table>
<thead>
<tr>
<th>PROJECT TEAM</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Julianne Bagley, SRNA</td>
<td>Lead</td>
</tr>
<tr>
<td>Naomi Song, SRNA</td>
<td>Lead</td>
</tr>
<tr>
<td>Erica Yi, SRNA</td>
<td>Lead</td>
</tr>
<tr>
<td>Dr. Ignacio Badiola</td>
<td>Site lead</td>
</tr>
<tr>
<td>Dr. Holly Brogan</td>
<td>DNP faculty lead</td>
</tr>
</tbody>
</table>
Appendix C

Gantt Chart
Appendix D

Prisma Flow Diagram