7-10-2018

Anesthesia Considerations for Spinal Anesthesia in Infants

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Anesthesia Considerations for Spinal Anesthesia in Infants

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Bachelor of Science in Nursing, University of North Dakota, 2012

An Independent Study

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Science

Grand Forks, North Dakota

December

2018

PERMISSION

Title	Anesthetic Considerations for Spinal Anesthesia in Infants
Department	Nursing
Degree	Master of Science

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ABSTRACT

Title: Anesthesia Considerations for Spinal Anesthesia in Infants

Background: The number of infants undergoing inguinal hernia repair is growing due to advances in neonatal care. This population is prone to a number of adverse effects from general anesthesia, particularly postoperative apnea. There is a growing interest to determine if spinal anesthesia will decrease the incidences of postoperative apnea.

Purpose: The purpose of this literature search is to determine if spinal anesthesia deceases the incidence of postoperative apnea compared to general anesthesia in the neonate population. The literature search will also discuss the differences of spinal anesthesia in infants compared to adults.

Process: The literature search was conducted using the databases PubMed, CINAHL, The Cochrane Library, and AccessMedicine. The databases were accessed through the University of North Dakota's Health Sciences Library. The literature search was limited to the past 15 years. Additional literature was found through the reference list of reviewed articles.

Results: The review of literature revealed a decrease in incidence of postoperative apnea when spinal anesthesia was used compared to general anesthesia in a majority of the studies.

Implications: Spinal anesthesia can be used safely and effectively in the neonatal populations, particularly those at an increased risk for postoperative apnea.

Keywords: Infant, neonate, spinal anesthesia, apnea, inguinal hernia, and postoperative apnea

Anesthesia Considerations for Spinal Anesthesia in Infants

Spinal anesthesia is a common neuraxial block performed in the adult population and offers many known benefits compared to general anesthesia. With advancements made in neonatal care of premature infants, more neonates are requiring surgery. Of those surgeries, inguinal herniorrhaphy is one of the most common procedures performed (Jones, Craven, Lakkundi, Foster & Badwi, 2015). More evidence is emerging to support the use of spinal anesthesia in the neonate population undergoing inguinal hernia repair to utilize these potential benefits, particularly decreasing postoperative apnea (Gupta & Saha, 2014).

Postoperative apnea is thought to occur from an immune respiratory central control mechanism and upper airway obstruction caused by decrease in muscle tone when undergoing general anesthesia. Postoperative apnea can lead to hypoxia and bradycardia. If the apnea is left untreated, the decrease in cerebral blood flow and oxygenation can cause brain ischemia and/or intracranial bleeding. Thus creating a situation for potential long-term brain damage. (Jones et al, 2015).

Case Report

A 14 day old, 2.54 kg male who presented for a left orchioplexy, left inguinal hernia repair due to a left cryptorchidism, and circumcision due to phimosis. The procedures were planned to be performed under spinal anesthesia. The patient's past medical history included a premature birth at 34 weeks, a unilateral high scrotal testicle, and nutritional intake less than requirements. The patient had no known allergies. Prior to surgery, the patient was admitted to the hospital and he been on 10% dextrose at 11 mL/hr. The pre-operative airway was unable to be assessed due to patient cooperation. Pre-operative labs were unremarkable. Pre-operative vital signs were, heart rate 143/min, blood pressure 78/47 mm Hg, respiratory rate 54/min, oxygen saturation of 100% and temperature 36.8 degrees Celsius. The patient received 80 mg of acetaminophen rectally prior to the procedure.

When the patient arrived to the operating room pulse oximetry, 3 lead electrocardiogram, and non-invasive blood pressure cuff were applied. End tidal carbon dioxide (CO2) was continuously monitored throughout the duration of the case. No pre-operative sedatives were administered prior to the arrival in the operating room or before the spinal placement. An intravenous (IV) infusion of NS 20 mEq in 10% dextrose continued at 11 mL/hr. The patient was then placed in the left lateral position and subarachnoid block landmarks identified. The interspace between L4 and L5 was chosen. The site was prepped with betadine in the normal sterile fashion and 1% lidocaine was used to form a skin wheel with a 25-gauge 1.5-inch needle. A 25-gauge, 5 cm pencil point needle tip needle was inserted into the L4-L5 interspace and cerebral spinal fluid (CSF) flow was obtained. CSF was aspirated and 0.6 mL of 0.5% bupivacaine was administered over 30 seconds. The patient was then placed supine for several minutes. The patient's legs were assisted to bed to prevent the legs from rising. Motor weakness was observed first, which lead to loss of motor movement. Sensory sensation was tested and determined adequate for the surgical procedure.

The surgical procedures lasted 84 minutes. 70 minutes into the procedure the patient showed discomfort and 2 mL of 24% sucrose was placed on the patient's pacifier. The patient showed discomfort again 80 minutes into the procedure and another 2 mL of 24% sucrose was applied to the patient's pacifier. Vital signs remained within normal limits during the procedure. The patient received a total of 21.1 mL of D10% during the procedure. Estimated blood loss was 1 mL. The patient was then transferred to the neonatal intensive care unit following the procedure. No episodes of postoperative apnea were reported. The patient was discharged two days following the procedures.

Literature Search

To guide my research a PICO question was developed in regards to the use of spinal anesthesia on premature infants and the effect spinal anesthesia has on postoperative apnea. PICO stands for patient population, intervention, comparison, and outcome (Stillwell, Fineout-Overholt, Melnk, & William, 2010). In neonates, does the use of spinal anesthesia compared to general anesthesia decrease postoperative apnea?

Databases

The databases accessed for this PICO question included PubMed, AccessMedicine, and The Cochrane Database. PubMed, AccessMedicine, and The Cochrane database were accessed through the University of North Dakota Health Science Library.

Vocabulary and Limitations

The terms "infant spinal anesthesia postoperative apnea" were searched on The Cochrane Database. The search resulted in one article. The article was relevant to the topic. Five additional articles were reviewed, which had been cited by the initial article.

Using the CINAHL database terms "spinal anesthesia", "infant", and "postoperative apnea" were entered in the search tabs. The search resulted in six articles. The articles were then limited to a publication date between 2009 and 2018, resulting in three pertinent articles.

Using the PubMed database Mesh terms “infant”, “neonate”, “spinal anesthesia”, and “apnea” were searched resulting in twenty-five articles. The search was then limited to articles published between 2000 and 2018 and the English language resulting in fourteen articles. Eight articles were used for the literature search. Additional articles were reviewed from articles listed in the references.

Review of Literature

In order to understand the effect spinal anesthesia has on postoperative apnea, one must know the anatomical, physiological, and pharmacological differences between neonate and adult spinal anesthesia. A neonate is considered to be less than four weeks old. An infant is considered to be older than 4 weeks to one year old (Nagelhout & Plaus, 2014). Literature topics covered include, the anatomy of the vertebral column and spinal cord, patient positioning, physical landmarks, spinal needle size, spinal approaches, and local anesthetics. Following with be a review of studies comparing the effects of spinal anesthesia compared to general anesthesia. Throughout the studies review, terminology inconsistencies were found between the neonate and infant populations. These inconsistencies made it challenging to compare these patient populations accurately.

Spinal Anesthesia

Spinal anesthesia is a type of neuraxial block, where a local anesthetic is injected into the subarachnoid space. In the subarachnoid space the local anesthetic comes into contact with the cerebral spinal fluid, allowing the local anesthetic to spread to the proposed site of action at the nerve roots (Butterworth, Mackey, & Wasnick, 2013).

The use of spinal anesthesia in the pediatric population has been around since the 1900’s. However, due to improvements and advancements made to general anesthesia over this time, spinal anesthesia fell by the wayside. That was until the 1980's, when a focus was placed to decrease postoperative apnea and bradycardia in the preterm infant and neonate population (Gupta & Saha, 2014).

Anatomy

A strong understanding of the anatomy of the vertebral column and the spinal cord is required in order to safely and successfully perform a spinal anesthetic, especially in the neonatal population. There are many anatomical, physiological, and pharmacological differences between neonatal and adult spinal anesthesia.

The vertebral column is composed of 33 vertebrae, starting at the base of the skull and ending at the tip of the coccyx. Of the 33 vertebrae 7 are cervical, 12 are thoracic, 5 are lumbar, 5 are sacral vertebrae fused together, and 4 are coccygeal vertebrae are fused together (Nagelhout & Plaus, 2014). The vertebrae form the spinal canal, which is composed anteriorly by the vertebral body, posteriorly by the spinous and lamina, and laterally by the transverse processes and pedicles. Intervertebral discs connect the vertebrae to each other. Facet joints are created by the inferior and superior articulate processes. The intervertebral foramina are formed by the superior and inferior pedicles, allowing the spinal nerves to exit (Butterworth, Mackey, & Wasnick, 2013).

The vertebral column is also supported by a series of muscles and ligaments. The anterior and posterior longitudinal ligaments support the vertebral bodies and intervertebral disks ventrally. The supraspinous ligament, interspinous ligament and ligamentum flavum support the vertebral column dorsally (Butterworth, Mackey, & Wasnick, 2013). The apices of the spinous process from C7 to the sacrum are connected by the supraspinous ligament. The interspinous ligaments are between adjacent spinous processes. The strongest ligament is ligamentum flavum, which connects paired lamina of the adjacent vertebrae (Morton, Foreman, & Albertine, 2011).

The spinal cord is located within the spinal canal. The spinal cord starts at the medulla oblongata, which is congruent with the C1, and ends at the conus medullaris, which is congruent with the L1 in adults (Morton, Foreman, & Albertine, 2011). A small percentage of adults have their spinal cord extend down to L2 (Nagelhout & Plaus, 2014). In neonates, the spinal cord also beings at the medulla oblongata but terminates at the L3. A series of nerve roots extend off of the conus medullaris, to approximately L5, called the cauda equine (Nagelhout & Plaus 2014).

From the foramen magnum to the end of the cauda equina three layers of membranes called the meninges cover the spinal cord. The outer most and thickest layer of meninges is called the dura matter (Nagelhout & Plaus, 2014). The dural sac terminates at S2 and adults and at S3 in neonates (Gupta & Saha, 2014).

The middle layer of meninges is called the arachnoid matter. Beneath the arachnoid matter is the subarachnoid space, where CSF is located. CSF is produced by the choroid plexus and absorbed by the arachnoid villi. The rate of CSF produced is 30 mL/hr and is replaced every 4 hours (Nagelhout & Plaus, 2014). In adults the total amount of CSF is about 2 mL/kg. In infants the total CSF can range between 4 mL/kg to 10 mL/kg (Libby, 2009: Gupta & Saha, 2014). The amount of spinal CSF also differs between adults and neonates. Neonates have nearly 50% of the total CSF around their spinal cord, compared to 33% in adults (Gupta & Saha, 2014).

The inner most layer of the meninges that directly adheres to the spinal cord is the pia mater (Nagelhout & Plaus, 2014). The pia matter is not very vascular in adults. However in neonates, the pia mater is highly vascular (Gupta & Saha, 2014).

Procedure Position

The spinal anesthetic starts with the patient in a sitting or lateral position. Position of the patient can be determined by practitioner preference. Of the studies reviewed three specified their patient position. Lambertz et al. (2014) conducted a cohort study involving 100 infants under the age of 6 months, whom underwent inguinal hernia repair. Lambertz et al. (2014) had a spinal failure in 7 of 76 patients for a spinal failure rate of 9.08 % in the sitting position.

Verma et al. (2014) and Somri et al. (1998) conducted their studies on spinal anesthesia in infants and children in the lateral position. Verma et al. (2014) conducted a one-year cohort study involving 102 pediatric patients. Of the patients involved in the cohort study 3 patients or 2.9%, did not achieve a satisfactory block. A satisfactory block was determined to be successful if the patient did not respond to surgical stimuli (Verma et al., 2014). Somri et al. (1998) conducted a randomized control trial involving 40 infants undergoing inguinal hernia repair. The 40 infants were assigned to two groups based on the type of anesthesia received, either spinal or general. Of the 24 patients selected for spinal aesthesia, 3 infants did not achieve successful CSF observation for a spinal failure rate of 12.5% (Somri et al., 1998).

The Vermont Infant Spinal Registry conducted a cohort study to assess the safety and efficacy of infants undergoing spinal anesthesia. During the cohort study 1554 infants had spinal anesthesia. The position of the infant was determined by the anesthetist preference using either the sitting or lateral position. The spinal failure rate for The Vermont Infant Spinal Registry was 3.6% (Williams Adams, Aladhem, Kreutz, Sartorelli, Vane, & Abajain, 2006). To determine if spinal anesthesia success rates are related to patient position more studies would need to be conducted.

When the neonates are placed in the proper position, it is important to avoid excessive flexion of the neck. When adults are placed in this position, they are able to maintain their airway. However, when a neonate experiences an excessive amount of neck flection, it can cause an upper airway obstruction, potentially resulting in hypoxia (Gupta & Saha, 2014).

Landmarks

The physical landmarks of the iliac crests are identified to determine an appropriate intervertebral space for needle placement. The iliac crests can identify intervertebral spaces anywhere from L3-L4 to L5-S1 depending on the individual (Nagelhout & Plaus, 2014). Using the iliac crests as iliac landmarks is appropriate for neonates, as the intercristal line still represents L4-L5 or L5/S1 (Gupta & Saha, 2014). After an intervertebral space is identified, the spinal tray is opened and sterile gloves are applied. An aseptic solution is applied to the patients back, allowed to dry, and a sterile drape is applied to the patient's back. A skin wheel is created using 1% lidocaine to anesthetize the needle injection side and surrounding tissues (Nagelhout & Plaus, 2014).

Spinal Needle Size

For the case report a 25-gauge spinal needle was utilized without an introducer. Among the articles reviewed for the literature review needle gauges ranged from 22 to 29 gauges. The University of Vermont used a 25-gauge needle in 53% of their causes followed by, a 22-gauge in 43%, and 26-gauge in 3.9%. Gupta and Saha (2014) found the puncture characteristics of the 25-gauge catheter were favored compared to the 29-gauge needle. In adults it is recommended if a 25 gauge or smaller spinal needle is used, an introducer will need to be inserted first (Nagelhout & Plaus, 2014). However, of the literature reviewed none mentioned the use of a transducer while performing spinal anesthesia.

Midline and Paramedian Approaches

When using the midline approach, the introducer will go through the supraspinous ligament and into the interspinous ligament. The spinal needle is then inserted through the introducer, going through the remaining interspinous ligament, and ligamentum flavum. As the needle continues, a distinct pop is felt as the needle passes though the dura (Nagelhout, & Plaus, 2014). The spinal ligaments of neonates are not as densely packed as adults. This makes the identification of ligaments through loss of resistance more difficult (Gupta & Saha, 2014).

During the paramedian approach, the introducer and needle insertion point is 1 cm lateral to the interspace. With the paramedian approach, the supraspinous ligament and the interspinous ligaments are bypassed. The spinal needle proceeds through the ligamentum flavum and the dura matter before the subarachnoid space is reached. While the paramedian approach is a great approach for calcified or degenerating ligaments, it is not recommended from neonates due to the lamina being cartilaginous (Nagelhout & Plaus, 2014:Gupta, Saha, 2014).

Correct placement is confirmed with the observed CSF drainage as the stylet is removed. Gupta and Saha (2014) used a 0.03 x cm to calculate the estimated distance in mm from skin to the subarachnoid space. The additional formula of 2 x kg +7 can also be used to estimate the distance to the subarachnoid space (Gupta & Saha, 2014). The local anesthetic of choice is then injected (Nagelhout, & Plaus, 2014). For neonate's it is recommended to inject the volume of local anesthetic over 20 seconds (Gupta & Saha, 2014).

Local Anesthetic

Local Anesthetics are classified into two groups called aminoesters or aminoamides. The intermediate chain binding the benzene ring to the quaternary amine determines the classification of local anesthetics. In aminoesters the intermediate chain is an ester. The aminoamides have an amide intermediate chain (Nagelhout & Plaus, 2014).

The mechanism of local anesthetics is to reversibly bind to voltage gated sodium channels of nerve fibers. Binding of the local anesthetics occurs when the sodium channel is in the open or inactive state. When binding of the sodium channel occurs there are 3 main types of nerve fibers that are blocked type A, B, and C. Type A is further divided into subgroups called A-alpha, A-beta, A-gamma, and A-delta. The groups and subgroups are based on the diameter of the nerve fiber and the degree of myelination (Nagelhout & Plaus, 2014).

Each group and subgroup is responsible for a different function. The type B fibers, which involve the preganglionic autonomic response, differ from adults and neonates. Compared to adults, neonates have minimal hemodynamic changes when type B nerve fibers are blocked (Libby, 2014). The decrease in hemodynamic changes have been related to an immature sympathetic nervous system, decreased peripheral blood volume, and a reduction in vagal efferent activity (Gupta & Saha, 2014).

The hemodynamic changes of premature infants undergoing spinal anesthesia were evaluated in a 44 patient observational study. All neonate's were born premature with congenital hear disease and were having inguinal hernias repaired. Systolic blood pressure, diastolic blood pressure, and mean arterial blood pressure were measured prior the spinal. Blood pressure was then measured at 5, 10, 20, and 30 minutes and at the end of surgery. The study showed spinal anesthesia did not significantly reduce systolic blood pressure, diastolic blood pressure or mean arterial pressure. The average decrease in heart rate was 10 beats per minute, which the study determined was not clinically significant (Shenkman, Johnson, Zurakowski, Arnon, & Sethan, 2012).

Local Anesthetic Dosing

Compared to adults infants require a higher dose of local anesthetic when undergoing spinal anesthesia. The increase of local anesthetic is thought to be due to the increased amount of total CSF in neonates creating a larger volume of distribution (Libby, 2009). The increased volume of distribution dilutes the amount of local anesthetic, resulting in decreased duration of analgesia (Nagelhout & Plaus, 2014).

Of the literature reviewed, the most common local anesthetics used were bupivacaine and tetracaine. According to Butterworth, Mackey, & Wasnick (2013), the maximum does for bupivacaine and tetracaine is 3 mg/kg. Somrie et al. (1998) used 0.6-0.8 mg/kg of isobaric bupivacaine. For patients under 5 kg, Verma et al. (2014) used 0.5 mg/kg of hyperbaric bupivacaine. Shenkman et al. (2012) used 1 mg/kg of bupivacaine or tetracaine. Welllborn et al. (1990) directed a randomized control trial involving 36 infants undergoing inguinal hernia repair. The neonates were randomly assigned to a spinal anesthetic group or a general anesthetic group. In the spinal anesthetic group 0.4-0.6 mg/kg of tetracaine was used (Welborn et al., 1990).

The University of Vermont used hyperbaric tetracaine in 99% of the case with an average dose of 0.54 mg/kg. The range of 0.375 mg to 4.5 mg of tetracaine was reported through the cases reviewed (Williams et al., 2006). The 3 mg dose of bupivacaine exceeded the mg/kg dosages among the literature reviewed.

Local Anesthetic Duration

The duration of local anesthetics is primarily related to the amount of plasma protein binding. Alpha-1 glycoproteins primarily bind to local anesthetics. Albumin secondarily binds to albumin. When the local anesthetic becomes unbound, it is reabsorbed into the vascular system (Nagelhout & Plaus. 2014).

One of the limiting factors of spinal anesthesia in neonates is the short duration of block. The increased amount of cardiac output in neonates compared to adults, results in more blood flow to the spinal cord. The increase in blood flow to the spinal cord results in a faster distribution, uptake, and elimination of local anesthetics from the subarachnoid space. It is estimated an adult's motor regression is nearly 5 times slower than a neonates (Liddy, 2009). Libby (2009) found an average length of block to be 60 to 70 minutes when using bupivacaine. Somri et al. (1998) had 45.9-minute average of spinal block.

Similar to adults the duration of block has been shown to increase with the addition of epinephrine. Studies have shown adding 0.01mg epinephrine to 0.4 mg/kg of hyperbaric 0.5% tetracaine resulted in a block length of 109 minutes compared to 84 minutes without epinephrine. A study involving the addition of epinephrine to 0.5% isobaric bupivacaine showed the average duration of block to be 81 minutes compared to 70 minutes without epinephrine (Frawley & Ingelmo, 2010). Compared to the literature the spinal block with bupivacaine-exceeded expectations by lasting over 80 minutes. The addition of epinephrine to the 0.5% bupivacaine or using hyperbaric 0.5% tetracaine with epinephrine could have resulted in a longer block in the case report.

The addition of an intrathecal alpha-2 agonist have been shown to increase the duration of block in neonates. However, there have been conflicting studies as it relates to the incidence of postoperative apnea with intrathecal clonidine. One study reviewed by Frawley and Ingelmo (2010), showed a postoperative apnea rate of 18% when 1 microgram/kg of intrathecal clonidine was added to hyperbaric bupivacaine.

Sucrose

When the procedure begins to exceed the duration of the block, additional supplementation will be needed. The uses of 0.05 to 2 mL of 12 to 50% sucrose solution placed on the neonate's pacifier has been shown to provide analgesia for the infant. Sucrose is thought to provide analgesia by directly activating the opioid receptors, enhancing or releasing endogenous opioids (Frawley & Ingelmo, 2010). The addition of sucrose 2 mL 24% sucrose was beneficial to the case involved in the case report.

Complications

The possible complications of neonatal spinal anesthesia are similar to those associated with adults. Potential complications include cardio-respiratory insufficiency, high or total spinal anesthesia, systemic toxicity, postdural puncture headache, neuraxial hematoma, and infection (Gupta & Saha, 2014; Frawley & Ingelmo, 2010). High or total spinal anesthesia has been estimated to occur in 0.6% of infants (Gupta & Saha, 2014). The neonate's vertebral column only has one anterior concave curvature (Frawley & Ingelmo, 2010). This limits the thoracic kyphosis which can make the cephalad spread of local anesthetics more likely. Ensuring the neonate's legs are not elevated immediately after the injection of local anesthetic is a key component to reducing high or total spinals (Gupta & Saha, 2014).

Postoperative Apnea

Apnea in neonates can occur from immature central and peripheral chemoreceptors. The neonate's response to hypercapnia by increasing ventilation is reduced by the immature serotonergic neurons in the medulla, this leads to apnea. The primary peripheral chemoreceptor is the carotid body, which reacts to events such as hypoxia, hypercapnia and acidosis. As the neonate's inspired oxygen is increased the carotid bodies reset, producing a hypoxic response when PaO2 levels reach 50 to 70 mm Hg. If inspired oxygen is increased, denervation of the carotid bodies can occur, resulting in apnea (Mathew, 2011).

Postoperative apnea can be a life threatening complication of general anesthesia in infants, particularly in preterm infants (Jones, Craven, Lakkudi, Foster, & Badwin, 2015). Previous studies have reported postoperative apnea incidence rate as high as 49% (Ozdemir & Arikan, 2013). Postoperative apnea is thought to occur from an immaturely developed respiratory central control mechanism and under developed respiratory musculature (Jones et al., 2015).

Inhaled agents produce a decrease in muscle tone resulting in an increased likelihood of upper airway obstruction and lower airway collapse. The diaphragm and chest wall are also affected by the decrease in muscle tone increasing the likelihood of hypoxia. Inhalational agents also reduce the ventilator responsiveness of stimulations like carbon dioxide (Jones et al., 2015).

Infants with an increased risk of postoperative apnea have been associated with postconceptual age less than 60 weeks, previous episodes of apnea, anemia, and low birth weight (Lee, Gleason, & Sydorak, 2011). Postconceptual age is determined by combining the infant's gestational age and their chronological age in weeks (Nagelhout & Plaus, 2014). Ozdemir and Arikan (2013), conducted a cohort study evaluating risk factors of premature infants undergoing inguinal hernia repair under general anesthesia. The 428 infants were divided into two groups based on postconceptual age. The first group included 191 infants with a postconceptual age less than 45 weeks. The second group included 237 infants with a postconceptual age between 45 and 60 weeks. Apnea occurred in 9 of the 191 (4.7%) patients in group one and 2 of 237 (0.8%) in-group 2. The authors concluded postconceptual age was the most important variable in predicting postoperative apnea. Additionally, previous history of bronchopulmonary dysplasia or necrotizing enterocolitis also increased the incidence of postoperative apnea (Ozdemir & Arkian, 2013).

Comparing Spinal and General Anesthesia

General anesthesia and mechanical ventilation has been associated with multiple complications, particularly in the preterm infant population due to associated comorbidities. These comorbidities, especially bronchopulmonary dysplasia can occur in up to 30% of neonates born at 32 weeks or less, are associated with an increased metabolic demand, altered oxygen diffusion capacity, a decrease in pulmonary functional capacity, and a decrease cardiorespiratory reserve. The respiratory depression caused from general anesthesia has been associated with 1 out of every 3 preterm infants developing atelectasis, aspiration pneumonia or apnea in preterm infants. The respiratory complications associated with general anesthesia and mechanical ventilation has led to anesthetists using regional anesthesia when appropriate in the infant population (Guria, Kuo, Kao, Christensen, & Holterman, 2017). The following studies have compared the effects of postoperative apnea with infants undergoing inguinal hernia repair experiencing general anesthesia or spinal anesthesia.

Davidson, Frawley, Sheppad, Hunt, and Haryd (2009) conducted a retrospective cohort study to investigate incidence in postoperative apnea and risk factors for failure of spinal anesthesia. During their review, 129 infants had an inguinal hernia repair. 29 infants had spinal anesthesia, 91 infants had general anesthesia, and 7 required supplemental anesthesia due to an ineffective block. Davidson et al. (2009) defined apnea "as any apnea observed and recorded in the patient record" (p.402). Apnea was further divided into early apnea, occurring within the first hour postoperatively, and late apnea occurring after the first hour of surgery.

Davidson et al. (2009) found no episodes of early apnea and one episode of late apnea in the 29 infants undergoing spinal anesthesia. Early apnea occurred in 6 of the 91 infants and late apnea occurred in 5 of the infants undergoing general anesthesia. One infant required an admission the intensive care unit following general anesthesia. In the group where supplemental anesthesia was performed 3 of the 7 infants experienced early apnea, while no infants had an episode of late apnea (Davidson et al., 2009).

Welborn et al. (1990) conducted a randomized control trial involving 36 former preterm infants comparing the incidence of postoperative apnea when spinal and general anesthesia is performed. The patients were randomly assigned to 3 groups. The first group of 126 patients had general anesthesia. The second group of 11 patients had spinal anesthesia. The third group of 9 patients had spinal anesthesia with 1-2 mg of intramuscular (IM) ketamine prior to the spinal. The results of the study showed postoperative apnea occurred in 8 of the 9 patients who received IM ketamine and spinal anesthesia. When no sedation was used prior to the spinal no episodes of postoperative apnea were reported. The general anesthesia group had 1 episode of postoperative apnea (Welborn et al., 1990).

Sormi et al. (1998) conducted a randomized control trial involving 40 high-risk infants to look at postoperative apnea incidences comparing spinal and general anesthesia. The infants were born less than 37 weeks gestation or a postconceptual age less than 60 weeks. Infants who also had a history of neonatal respiratory distress, bronchopulmonary dysplasia, or history of pre-operative apnea were included. Apnea was defined as a respiratory pause of 15 seconds or a respiratory pause less than 15 seconds with a heart rate less than 100 bmp (Sormi et al., 1998).

Results from the study showed 7 of the 20 patients in the general anesthetic group developed apnea. Of the 7 patients who developed apnea, 4 patients required post-operative mechanical ventilation. In the spinal anesthetic, 3 patients were unable to obtain successful lumbar puncture. Of the 17 patients, 1 patient developed apnea at 10 and 14 hours postoperatively (Sormi et al., 1998).

Gurri et al. (2016) conducted a retrospective cohort study to assess respiratory complications associated with regional or general anesthesia involving premature infants undergoing inguinal hernia repair. Patients included in the cohort study were born less than 32 weeks post gestational age and had the inguinal hernia repaired prior to being discharged from the NICU. As done in the case report, orchiopexies, and circumcisions were also performed during the study (Gurri et al., 2016).

A total of 95 patients were involved in the study. 58 patients underwent general anesthesia and 37 patients underwent regional anesthesia. Of the 37 patients who received regional anesthesia, 21% of patients received spinal anesthesia and the remaining 79% received a one shot epidural injection (Gurri et al., 2016).

Gurri et al. (2016) did not find a significant statistical difference between general and regional anesthesia as it pertains to decreasing postoperative apnea. However, postoperative apnea occurred in 15.5% of general anesthesia patients and 10.8% of regional anesthesia patients. A significant finding included almost 20% of general anesthesia patients remained intubated 4 hours past surgery (Gurri et al., 2016).

Davidson et al., (2015) conducted a randomized control trial comparing apnea and neurodevelopmental outcomes in infants undergoing awake-regional anesthesia and general anesthesia. The randomized control trial involved 7 countries and 28 sites. The 722 infants involved in the study were born after 26 weeks gestation and less than 60 weeks postmenstrual age, undergoing unilateral or bilateral inguinal herniorraphy. The awake-regional group was composed of 363 patients. Of those 363 patients, 222 received a spinal, 117 received spinal and a caudal block, and 7 received only a caudal. 70 patients in the awake-regional group were exposed to sedation or sevoflurane and were removed from the study (Davidson et al., 2015).

The patients were randomly selected into spinal or general groups and observed for episodes of apnea for 12 hours post operatively. Apnea was defined as “a pause in breathing >15 seconds or a pause >10 seconds if association with oxygen saturation <80%

or bradycardia (20% fall in heart rate)" (Davidson et al., 2015. p 42.). Apnea was then further broken down to early apnea, occurring within 30 minutes or late apnea occurring after 30 minutes to 12 hours, and after 12 hours postoperatively (Davidson et al., 2015).

The randomized control trial found postoperative apnea to occur in 6 out of 286 (2.1%) regional patients and 15 of 358 (4.2%) of general anesthetic patients. 12 patients developed early apnea in the general anesthetic group compared to 1 in the regional group. However, incidences of late apnea were similar in the two groups, 7 for the general group and 6 for the regional group. The study concluded there was a benefit to reducing early apnea using awake-regional anesthesia compared to general anesthesia. However, minimal difference was found on reducing late apnea using spinal anesthetic (Davidson et al., 2015).

Kim, Thorton, and Eipe (2009), conducted a retrospective cohort study involving 133 infants who underwent inguinal hernia surgery exploring the incidence of postoperative apnea between general and spinal anesthesia. The 133 infants were under 60 weeks of postconceptual age prior to surgery and were born at 37 weeks gestation or fewer. Apnea was determined to be a respiratory pause of 15 seconds or more (Kim, Thorton & Eipe, 2009).

The retrospective cohort study showed 4 of 63 (6.3%) of infants who receive a spinal anesthetic developed postoperative apnea. Of the 60 infants who experienced general anesthesia, 6 developed postoperative apnea resulting in an occurrence rate of 10%. Due to an insufficient block, a third group was created who had supplemental anesthesia. In this group 2 infants received nitrous oxide, 2 infants received IV ketamine, and 5 infants converted to general anesthesia with an endotracheal tube. Of the 9 patients involved in this group, 4 developed postoperative apnea (Kim, Thorton, & Eipe, 2009).

Recommendations for Anesthesia Professionals

Under the right circumstances including procedure type, procedure length and the comfort level of the anesthesia professional, spinal anesthesia should be preformed when possible. The procedure should not be expected to exceed 90 minutes (Gupta & Saha, 2014). Neonate inguinal hernia repair can be preformed under spinal anesthesia (Lambertz et al., 2014). Preoperative and intraoperative sedatives should be avoided to decease risk factors associated with postoperative apnea in infant spinal anesthesia (Shenkman et at., 2012). The use of oral sucrose solution is an acceptable adjunct for neonatal spinal anesthesia (Frawley & Ingelmo, 2010).

For local anesthetics, 0.5% bupivacaine, 0.5% tetracaine, and 1% tetracaine were most commonly used during the procedures. The variety of dosages reviewed makes recommendations on a specific dose difficult. The range of 0.5-1mg/kg of bupivacaine and 0.5-1 mg would be acceptable. The addition of an epinephrine wash would be recommended to maximize the duration of the block. The positioning of the patient should be based on the anesthesia professional's preference (Williams et al., 2006). The midline approach is recommended over the paramedian approach (Gupta & Saha, 2014). A 25-gauge spinal needle was most commonly used among articles reviewed.

Recommendations for future research would be to create a standardized definition of postoperative apnea. In the literature reviewed, multiple time lengths and differentiating criteria were used to identify postoperative apnea. Due to the majority of the key studies comparing spinal anesthesia and general anesthesia occurring beyond the past decade, future research is needed to make a more definitive conclusion.

Conclusion

Postoperative apnea in the neonatal population can lead to life threating emergency. While spinal anesthesia does not eliminate the side effect of postoperative apnea, it does eliminate the alteration of the central respiratory center and respiratory mechanics associated with general anesthesia. The literature does show a decreased incidence of postoperative apnea in neonates when spinal anesthesia is performed compared to general anesthesia. With this knowledge, for optimal patient outcomes, anesthesia professionals should consider utilizing spinal anesthesia rather than general anesthesia in the neonatal population whenever circumstances are appropriate.

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Appendix A

5/6/18

Anesthesia Considerations for Spinal Anesthesia in Infants

Cody Grassel, SRNA

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Case Information

- Orchiopexy, inguinal hernia repair, and circumcision
- 14 days old
- 2.54 kg
- Male
- ASA 2

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Pre-operative Evaluation

- Past Medical History
  - Premature birth at 34 weeks
  - Unilateral high scrotal testicle
  - Nutritional intake less than requirements
- No previous surgical history
- Pre-op VS
  - Heart rate 143/min
  - Blood pressure 78/47 mm Hg
  - Respiratory rate 54/min
  - Oxygen saturation 100% on room air
  - Temperature 36.8 C
- Unable to evaluate airway

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Anesthetic Course

- Spinal Anesthesia
  - Lateral position
  - 25 gauge 5 cm spinal needle
  - L4-L5 interspace
- Drugs
  - 80 mg acetaminophen
  - D10 IV at 11 mL/hr
  - 0.6 mL of 0.5% bupivacaine
  - 2 mL of 24% oral sucrose solution x2

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Intraoperative Issues

- About 70 minutes into the procedures the patient started to show signs of discomfort.
- 2 mL of 24% oral sucrose solution was placed on the patients pacifier.
  - Intervention was repeated 5 minutes later.

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PACU

- The patient was transferred to the back to the NICU.
- Vital signs were within normal limits.
- No episodes of postoperative apnea.
- The patient was discharged home 2 days later.

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Neonate Spinal Anatomy

- The spinal cord begins at the medulla oblongata and terminates at L3.
- In neonate's the dural sac terminates at S3.
- The neonate's pia mater is highly vascular.
- The iliac crests represent the levels L4-L5 or L5-S1.
- The vertebral column has one anterior concave curvature.
- Spinal ligaments in neonates are less dense than adults.
- The neonate's lamina are cartilaginous.

(Morton, Foreman, & Albertine, 2011; Gupta & Saha, 2014; Frawley & Ingelmo, 2010)

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Cerebral Spinal Fluid

- In infants the total amount of CSF is 4 mL/kg and neonates as high as 10 mL/kg.
  - In adults the total amount of CSF is about 2mL/kg.
- Neonate's have nearly 50% of the total CSF around their spinal cord.
  - In adults an estimated 33% is around the spinal cord.

(Nagelhout & Plaus, 2014; Gupta & Saha, 2014)

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Hemodynamic Response

- The preganglionic autonomic response during spinal anesthesia in neonates is minimal compared to adults.
- It is related to an immature sympathetic nervous system, decreased peripheral blood volume, and a reduction in vagal efferent activity.

(Libby, 2009; Gupta & Saha, 2014)

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Neonate Spinal Anesthesia

Positioning

- Performed in the sitting or lateral position.
  - Excessive neck flexion can lead to airway obstruction.
- The University of Vermont suggests position to be determined based off of the providers preference.
- The Vermont Infant Spinal Registry performed spinal anesthesia on 1554 infants during a retrospective cohort study.
  - The spinal failure rate was 3.6%.

(Williams, Adams, Aladjem, Kretuz, Sarorelli, & Vane, 2006)

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Neonate Spinal Anesthesia

Spinal Needle Gauges

- Among the reviewed literature, spinal needle gauges ranged form 22-29.
- The distance from skin to subarachnoid space in mm can be estimated by two equations:
  - 0.03 x height in cm
  - 2 x kg +7

(Willams et al., 2006; Gupta & Saha. 2014)

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Neonate Spinal Anesthesia

Complications

- Cardio-respiratory insufficiency
- High or total spinal anesthesia
- Systemic toxicity
- Postdural puncture headache
- Neuraxial hematoma
- Infection

(Gupta & Saha, 2014)

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Neonate Spinal Anesthesia and Local Anesthetics

Dosing

- Neonates require a larger mg per kg dose of local anesthetics compared do adults undergoing spinal anesthesia.
- The increased amount of CSF creates a larger volume of distribution, diluting the local anesthetic.

(Libby, 2009)

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Neonate Spinal Anesthesia and Local Anesthetics

Dosing

- 0.5 mg/kg of hyperbaric bupivacaine (Verma et al., 2014).
- 0.6-0.8 mg/kg of isobaric bupivacaine (Somri et al., 1998).
- 1 mg/kg of bupivacaine (Shenkman et al., 2012).
- 0.4-0.6 mg/kg of tetracaine (Wellborn et al., 1990).
- 0.54 mg/kg tetracaine (Williams et al., 2006).
- 1 mg/kg of tetracaine (Shenkman et al, 2012).

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Neonate Spinal Anesthesia and Local Anesthetics

Duration

- The duration of local anesthetics in neonates undergoing spinal anesthesia is significantly shorter than in adults.
- The increased cardiac output in neonates results in increased blood flow to the spinal cord.
- The increase in blood flow to the spinal cord results in a faster distribution, uptake, and elimination of local anesthetics from the subarachnoid space.

(Libby, 2009)

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Neonate Spinal Anesthesia and Local Anesthetics

Duration

- The addition of epinephrine increases the duration of the block in infants.
- Epinephrine increased the average duration of block from 84 minutes to 109 minutes in hyperbaric tetracaine .
- Epinephrine increased the average duration of block from 70 minutes to 81 minutes isobaric bupivacaine .

(Frawley & Ingelmo, 2010)

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Sucrose

- The uses of 0.05 to 2 mL of 12 to 50% sucrose solution placed on the neonate's pacifier has been shown to provide analgesia for the infant.
- Thought to provide analgesia by directly activating the opioid receptors, enhancing or releasing endogenous opioids.

(Frawley & Ingelmo, 2010)

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Postoperative Apnea

- Postoperative apnea (POA) can be an emergent situation in neonates.
- In the past POA has been reported to occur in 49% of general anesthetic cases involving preterm infants. The more recent literature shows a POA rate of 5%.
- POA has been defined by the length of respiratory pause or respiratory pause associated with bradycardia or decreased oxygen saturation.

(Libby, 2009)

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Postoperative Apnea

- Infants have immaturely developed respiratory central control mechanism being further effected by inhalational agents.
- Inhaled agents produce a decrease in muscle tone resulting in an increased likelihood of upper airway obstruction and lower airway collapse.
- The diaphragm and chest wall are also affected by the decrease in muscle tone increasing the likelihood of hypoxia.

(Jones, Craven, Lakkudi, Foster & Badawi, 2015; Mathew, 2011)

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Postoperative Apnea

- Risk factors for POA include
  - Gestational age less then 60 weeks
  - Previous episode of apnea
  - Anemia
  - Low birth weight
  - Anesthetic agents
  - Bronchopulmonary dysplasia

(Robles-Rubio, Brown, Bertolizio, & Kearney, 2104; Ozdemir & Arikan, 2013)

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Spinal Anesthesia Compared to General Anesthesia

- Kim, Thorton, and Eipe (2009), 133 infants who underwent inguinal hernia surgery.
- Spinal anesthesia
  - 4 of 63 infants experienced POA (6.3%)
- General anesthesia
  - 6 of 60 infants experienced POA (10%)
- Spinal Supplementation
  - 4 of 9 infants experienced POA (44.4%)

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Spinal Anesthesia Compared to General Anesthesia

- Davidson et al. (2009) a cohort study of 129 infants undergoing inguinal hernia repair.
- Spinal Anesthesia
  - Early apnea occurred in 0 of 29 infants.
  - Late apnea occurred in 1 of 29 infants.
- General Anesthesia
  - Early Apnea occurred in 6 of 91 infants
  - Late apnea occurred in 5 of 91 infants.
- Spinal Supplementation
  - Early apnea occurred in 3 of 7 infants.
  - Late apnea occurred in 0 of 7 infants.

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Spinal Anesthesia Compared to General Anesthesia

- Davidson et al., (2015) 722 infants undergoing inguinal hernia repair involved in the randomized control trial.
- Awake Regional Group
  - Postoperative apnea occurred in 6 of 286 infants (2.1%).
    - Early apnea occurred in 1 of 286 infants.
    - Late apnea occurred in 6 of 286 infants.
- General Anesthesia Group
  - Postoperative apnea occurred in 15 of 358 infants (4.2%).
    - Early apnea occurred in 12 of 358 infants.
    - Late apnea occurred in 7 of 358 infants.

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Spinal Anesthesia Compared to General Anesthesia

- Gurri et al. (2016) cohort study of premature infants undergoing inguinal hernia repair.
- Regional Anesthesia
  - POA occurred in 10.8% of infants.
- General Anesthesia
  - POA occurred in 15.5% of infants.
  - 20% remained intubated 4 hours postoperative.

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Spinal Anesthesia Compared to General Anesthesia

- Sormi et al. (1998) conducted a randomized control trial involving 40 high-risk infants undergoing inguinal hernia repair.
- Spinal Anesthesia
  - 1 of 17 infants developed apnea at 10 and 14 hours postoperatively.
- General Anesthesia
  - 7 of 20 infants developed apnea.
  - 4 remained on mechanical ventilation postoperatively.

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Recommendations

- In neonates, spinal anesthesia can be preformed on inguinal hernia repairs.
- The procedure should be expected to be less than 90 minutes.
- Preoperative and intraoperative sedatives should be avoided.
- Positioning of the patient should be based on the anesthesia providers preference.
- The midline approach should be preformed.
- 0.5-1.0 mg/kg of bupivacaine.
- 0.5-1.0 mg/kg of tetracaine.

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Conclusion

- Neonatal spinal anesthesia has many differences compared to adults.
- Spinal anesthesia has been shown to decrease the incidence of postoperative apnea in infants under going inguinal hernia repair.
- Spinal anesthesia does not eliminate postoperative apnea, however it does eliminate the risk factors associated with general anesthesia.

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Thank You
Are There Any Questions?

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