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Adverse Events and Resource Utilization After Spinal and General Anesthesia in Infants Undergoing Pyloromyotomy

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Abstract

Background and Objectives—Interest in spinal anesthesia (SA) is increasing due to concern about the long-term effects of intravenous and inhaled anesthetics in young children. This study compared SA versus general anesthesia (GA) in infants undergoing pyloromyotomy.

Methods—Between 2000 to 2013, the University of Vermont Medical Center (UVMHC) almost exclusively used SA for infant pyloromyotomy surgery, while Columbia University Medical Center (CUMC) relied on GA. Outcomes included adverse events (AE) within 48 hours of surgery, operating room (OR) time, and postoperative length of stay (LOS). Regression was used to evaluate the association between anesthesia technique and outcomes, accounting for demographic and clinical covariates.

Results—We studied 218 infants with SA at UVMHC and 206 infants with GA at CUMC. In the SA group, 96.3% of infants had adequate initial analgesic levels but 35.8% required supplemental IV or inhaled anesthetic agents. Compared with GA, the risk of AEs in SA (adjusted odds ratio [aOR], 0.60; 95% CI, 0.27 – 1.36) did not differ, but SA was associated with shorter OR times

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(17.5 minutes faster; 95% CI, 13.5 – 21.4 minutes) and shorter postoperative LOS (GA is 1.19 times longer; 95% CI, 1.01 – 1.40).

Discussion—Infants undergoing pyloromyotomy with SA had shorter OR times and postoperative LOS, no differences in AE rates, and decreased exposure to intravenous and inhaled anesthetics, although SA infants often still required supplemental anesthetics. Whether these differences result in any long-term benefit is unclear; further studies are needed to determine the risk of rare AEs, such as aspiration.

Introduction

While commonly used intravenous and inhaled anesthetic agents cause neurotoxic effects in animals, the association between early anesthetic exposure and long-term cognitive deficit is less clear, with no association found in the one published prospective study to date.¹⁻¹⁰ Despite this uncertainty, there is mounting concern in the medical community, with some recommending that elective surgery be delayed in children under age 3.¹¹ Few procedures at this age however are purely elective, and in the vast majority of pediatric surgeries, general anesthesia (GA) with inhaled and intravenous agents is the standard technique.^{12;13} In response to the concern of potential neurotoxicity in children, the use of awake spinal anesthesia (SA), has been proposed, which in certain situations may allow the avoidance of inhaled and intravenous anesthetics entirely.^{10; 14}

Spinal anesthesia is a technique commonly used in anesthetic practice and employed for intra-abdominal and lower extremity procedures. In experienced hands, success rates of achieving a block level adequate to begin surgery in infants reach over 95%.^{14; 15} In centers that do not use SA as a first line anesthetic technique, 93.2% success rates have been reported.¹⁶ However, since SA is most commonly studied in children with inguinal hernia repair, its effectiveness in lengthier surgeries with higher levels of surgical stimulation is less clear.^{14; 15; 17} In this study we chose children undergoing pyloromyotomy because they are often otherwise healthy full-term infants, and while medical management for pyloric stenosis may be an option, the treatment is typically surgical and performed within a discrete age window where vulnerability to anesthetic neurotoxicity may occur.¹⁸ Also to our knowledge no large-scale comparison of anesthetic technique in infants with pyloromyotomy has been performed. The purpose of this study is to evaluate 1) perioperative adverse events (AE), and 2) resource utilization in infants undergoing pyloromyotomy with SA vs. GA.

Methods

The University of Vermont Medical Center (UVM) uses regional anesthesia (either spinal or epidural anesthesia) as its preferred anesthetic technique for all infant surgery below the level of the chest, and almost exclusively uses spinal anesthesia for pyloromyotomy surgery, while Columbia University Medical Center (CUMC) almost exclusively uses general anesthesia. In this study we took advantage of an “experiment in nature” by evaluating perioperative differences in infants receiving SA from UVM and GA from CUMC. Patients at UVM where GA was the planned anesthetic and therefore no SA attempts were made, and patients at CUMC where SA was attempted were excluded from analysis.

Data Source

Following IRB approval, billing records were obtained from CUMC and UVM for all patients under age 12 months who had surgery from January 1, 2000 to January 31, 2013. Patients who had undergone pyloromyotomy were identified using Current Procedural Terminology codes, and anesthetic and medical records for these patients were reviewed. At CUMC, medical records for surgeries performed between 2000 and 2002 were not available and those infants were excluded. Infants who required mechanical ventilation immediately prior to surgery, or had a history of extracorporeal membrane oxygenation, open-heart surgery, or neurosurgical procedures prior to pyloromyotomy were excluded. Paper anesthetic records were used prior to January 2008 at UVM and August 2008 at CUMC, and subsequently electronic records were available. Data was collected by trained research assistants (AFF and AR) and reviewed by board certified pediatric anesthesiologists (CI, RKW, SL). All data was entered into a secure online web-based database hosted at CUMC.

Outcomes

Perioperative AEs were defined as events specified by Wake Up Safe, the Quality Improvement Initiative of the Society for Pediatric Anesthesia, or outcomes used in the Pediatric Regional Anesthesia Network (PRAN) database study.¹⁹⁻²¹ Events were included if they could be attributed to anesthetic care, were applicable to an infant population, and occurred within 48 hours of pyloromyotomy. The AEs were categorized into three broad groups: 1) Major, 2) Respiratory, and 3) Regional anesthesia related (Table 1). The presence of blood in the spinal needle was not considered to be a hematoma or vascular puncture AE, defined by the PRAN study as “the presence of blood with aspiration”.^{19; 20}

Evaluation of resource utilization included assessment of length of time in the operating room (OR) as well as hospital length of stay following surgery. The length of time in the OR was defined as the documented time between the patient entering the OR and the time the patient exited the OR after completion of the procedure. Surgical time could not be calculated due to inconsistencies in documentation of surgical start and stop times. The types of medications and number of doses of anesthetics used in both groups of patients were also assessed to determine levels of anesthetic exposure. The start of inhaled gas administration was defined as the time when the gas was first administered, and the stop when it was no longer documented on the paper record, or when there was no longer inspired anesthetic gas recorded on the electronic anesthetic record.

Statistical Analysis

The presence of an AE was coded as a binary variable and was initially evaluated using chi-square. The a priori P-value was set to $P < 0.05$. Regression was used to adjust for baseline demographic and clinical variables with age and weight as continuous variables, and gender, gestational age (< 37 weeks), and ASA status (> 2) as categorical variables. Logistic regression was used for the categorical AE outcome, linear regression for length of OR time, and Poisson regression for hospital LOS. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC).

Spinal Anesthesia Technique

Infants were brought into the OR and awake oral gastric suctioning was performed to empty the stomach. Lumbar puncture was performed in the sitting or lateral decubitus position with a midline approach at the L3/L4 or L4/L5 level. Cerebrospinal fluid (CSF) was obtained using a 22 or 25 gauge Quincke needle, and local anesthetic with epinephrine in a 1-mL tuberculin syringe was injected to produce a subarachnoid block. Following block placement, the infant was turned supine with a small shoulder roll placed to reduce rostral spread of the local anesthetic. Adequacy of the sensory level of spinal block was judged initially by observation of motor weakness in the lower extremities and then a lack of response to skin pinch at the dermatomal level where incision was to be made. If a sufficient sensory level could not be obtained, the block was considered a failure and the child was intubated and maintained under general anesthesia for the procedure.

General Anesthesia Technique

Infants were brought into the OR and awake oral gastric suctioning was performed to empty the stomach. Patients were placed in the supine position and intubated awake or using a rapid sequence intubation (RSI) technique. The decision to perform either an awake intubation or RSI was based on attending preference. At the end of the procedure, patients were extubated awake.

Results

Records were obtained for 226 infants from UVM and 207 infants from CUMC who had pyloromyotomies, for a total of 433 infants. SA was attempted in the vast majority of patients undergoing pyloromyotomy at UVM with attempts in 218 of 226 (96.5%) of patients. At CUMC, 206 of 207 (99.5%) patients had GA as the chosen anesthetic. After excluding the 8 pyloromyotomy patients from UVM where SA was not attempted due to surgeon preference, and the 1 infant from CUMC where SA was used due to congenital airway abnormality, the study cohort consisted of 218 infants from UVM with SA and 206 from CUMC with GA.

While the infants from the 2 groups were demographically similar, the GA group had a slightly higher acuity of illness with more ASA 3 and 4 patients than the SA group.(Table 2) Open pyloromyotomies were performed on all SA patients while in the GA patients, 47.1% (n=97) had an open procedure and the remainder had a laparoscopic procedure.

Spinal Anesthesia for Pyloromyotomy

SA was attempted in 218 patients. An adequate level of surgical anesthesia was obtained in 210 patients for an initial success rate of 96.3%. In the 8 SA patients where spinal fluid could not be obtained or an adequate spinal level was not achieved, GA was required, with 4 children receiving an RSI, 1 receiving an inhalational induction, and 3 intubated awake. An additional 7 patients were exposed to volatile anesthesia, with 2 experiencing an AE requiring intubation, and 5 having a block duration that was inadequate for completing the procedure, with 3 of those 5 patients needing intubation.

Tetracaine was the local anesthetic used in 210 patients (96.3%) where SA was attempted, with a mean dose of 0.77 ± 0.14 mg/kg. Of the 218 infants who had SA, 78 (35.8%) required a supplemental IV or inhaled anesthetic agent. Of these 78 infants, 37 (47.4%) received propofol, 13 (16.7%) received fentanyl, 35 (44.9%) received IV midazolam, and 15 (19.2%) received a volatile anesthetic. Of the 8 patients where SA failed and GA was required from the start of the procedure, 7 were exposed to sevoflurane for a mean duration of 56.4 ± 14.4 minutes, and 1 was exposed to halothane for 40 minutes. Of the 7 patients who needed volatile anesthetic after an initial adequate spinal anesthetic level, 5 were exposed to sevoflurane for a mean duration of 45.2 ± 15.7 minutes, 1 was exposed to nitrous oxide alone for 5 minutes, and one record had missing data. No differences in tetracaine dose were seen between infants who needed and did not need inhaled or IV anesthetic supplementation. Procedure durations were longer in infants who needed a supplement, but the difference was not significant (69 ± 13.4 minutes versus 64.9 ± 14.2 minutes; $P=0.054$).

General Anesthesia for Pyloromyotomy

In the GA group, awake ETT placement was initially attempted in 120 of 206 infants (58.3%) and IV induction with RSI was used in 86 of 206 (41.7%). Of the 120 patients where awake ETT was attempted, 31 (25.8%) ultimately required RSI, due to difficulty with awake intubation. All 206 infants who had GA were exposed to volatile anesthetics: 164 were exposed to sevoflurane, for a mean duration of 58.8 ± 23.7 minutes, 38 were exposed to isoflurane for a mean duration of 47.1 ± 13.4 minutes, and 3 were exposed to desflurane for a mean duration of 66 ± 10.4 minutes. Four paper records documented administration of volatile anesthetics, but duration was not recorded. Of the 206 GA infants, 176 (85.4%) received propofol, 75 (36.4%) received fentanyl, 6 (2.9%) received remifentanyl, and no child received IV midazolam.

Adverse Events

In the SA group, 11 infants experienced an AE, while in the GA group, 16 infants, had an AE. The overall rate of AEs was 5.0% for SA and 7.8% for GA ($P=0.3$) (Table 3). While the rate of AE between the 2 institutions did not differ, the types of events varied. In the GA group all AEs were respiratory in nature with two patients experiencing postoperative apnea, and one having laryngospasm. The remaining 13 infants needed >3 direct laryngoscopy attempts. Of those 13 infants, 12 were attempted awake intubations while 1 was a dysmorphic child who required a fiberoptic intubation. Within the SA group, 4 had failed blocks and 4 had a spinal block abandoned due to difficulty with placement. The remaining AEs included one child who vomited and had laryngospasm requiring intubation but no documented signs of aspiration, another, who required a propofol bolus, became apneic and vomited but did not require intubation, and one child who had a high spinal requiring intubation.

There were no documented cases of postoperative apnea in the SA group. Although 13 SA patients required intubation due to inadequate spinal anesthesia or AE, all patients were extubated at the end of the procedure. At CUMC, 4 infants remained intubated and were transferred to the intensive care unit due to apneic episodes related to pre-existing congenital and metabolic disorders.

In evaluating AE rates using logistic regression, after accounting for gender, ASA 3, and gestational age < 37 weeks, there was still no difference between SA compared to GA (aOR, 0.60; 95% CI, 0.27 – 1.36). While failed/abandoned spinal blocks in the SA group and multiple direct laryngoscopy attempts in the GA group are defined as AEs in other patient safety studies, whether they should truly be classified as AEs is debatable. If those events are excluded, there is still no difference between SA and GA, with an AE rate of 1.9% in GA and 1.4% in SA ($P=0.6$), and this result remains even after adjusting for covariates (SA vs GA, aOR, 0.96; 95% CI, 0.19 – 4.90).

Resource Utilization

The OR times were faster with SA than GA, with mean times of 69 ± 18.3 vs 87.7 ± 22 minutes respectively ($P<0.0001$). While the unadjusted crude difference in time between GA and SA was 18.8 minutes (95% CI 14.9 – 22.6), after adjusting for gender, age at time of procedure, ASA 3, and gestational age < 37 weeks using linear regression, pyloromyotomy with GA was still found to take longer than SA, with GA taking 17.5 minutes longer (95% CI, 13.5 – 21.4) on average than SA (Table 4). The mean postoperative LOS was 1.31 days for SA and 1.68 days for GA while the median was 1 day for both SA and GA. Postoperative LOS was also found to be shorter in SA compared to GA after adjusting for covariates using Poisson regression. GA patients were found to have a postoperative LOS that was 1.19 times longer (95% CI, 1.01 – 1.4) than SA patients. The OR time based on surgical technique in the GA group was not found to differ significantly (85 ± 22.3 minutes for open vs. 90.3 ± 21.6 minutes for laparoscopic pyloromyotomy; $P=0.09$). However, to account for the fact that UVM did not perform laparoscopic procedures, we restricted to only open pyloromyotomies as a sensitivity analysis, finding that OR times for GA were 14.0 minutes longer (95% CI, 9.2 – 18.8) than SA, and postoperative LOS was 1.43 times longer (95% CI, 1.19 – 1.72) in GA than SA. In addition, to account for the possibility of ASA status not fully adjusting for the impact of illness in the sicker patients at CUMC, we also restricted to only ASA 1 and 2 patients, again finding that the results were unchanged.

Discussion

Observational studies comparing different anesthetic techniques are problematic because institutions often favor one technique over the other, with the alternate method chosen only under specific circumstances. For example, SA is used at CUMC for hernia procedures but typically only in premature infants at significant risk of apnea, or in children where avoidance of the airway is desired. In order to reduce this selection bias within each institution, we compared an institution that uniquely specializes in SA with one that almost exclusively performs GA for pyloromyotomy.

Neuraxial anesthesia is an important component of perioperative anesthetic and pain management, but studying SA in infants is challenging because GA is by far the favored method of anesthesia in children. In a survey of 47 pediatric institutions in Europe and Canada, 1262 regional blocks were performed without concomitant general anesthesia in a one-year period, while in the same period 134,482 general anesthetics were performed.¹³ In

a recent randomized trial between regional anesthesia and GA in 722 infants of whom 55% were premature, a slightly lower rate of apnea after regional anesthesia was found, but only within the first 30 minutes of completion of the surgical procedure.¹⁷ While SA may reduce respiratory complications in children undergoing hernia repair, this may not be directly applicable to patients undergoing other procedures and in populations with lower rates of prematurity.

In pyloromyotomies, we found the rate of achieving an adequate analgesic level to be 96.3%, which was similar to that published for all procedure types in a prior study at UVM.¹⁴ Infants in both groups experienced apnea and bronchospasm and laryngospasm, but those in the SA group also experienced a high spinal as well as a case of laryngospasm after vomiting during the procedure. While we did not find a difference in the rate of AEs between the two groups, it must be acknowledged that not all AEs are equal, with the more serious events occurring rarely. In infants with pyloric stenosis, a feared complication is aspiration. As the risk of aspiration in pediatric procedures may be as low as 1 in 2632 cases, evaluation of this event is challenging.²² A recent case series evaluated 252 infants who received a gas induction for pyloromyotomy with no aspiration events, but this study may also be underpowered for evaluating aspiration.²³ Since UVM and CUMC are both teaching institutions, some of the AEs attributed to failed/abandoned spinal or multiple attempts at intubation may be due to the inexperience of the trainees, and it is debatable if these should be included as AEs. However after removing these events, the rate of AEs between SA and GA was still similar. Since AEs were based on events specified by the Wake Up Safe And PRAN studies, the presence of blood in the spinal needle was not considered to be an AE. At UVM, if fluid in the spinal needle was determined to be CSF that was blood tinged, the local anesthetic dose would be injected. However if the blood did not clear, the attempt was considered to be a failure, the needle was removed, and an additional attempt was made if clinically indicated. The presence of blood in the spinal needle occurred in 37 (17%) of our SA patients and is likely dependent on the skill of the provider, with a rate of 12.4% in another experienced center and a rate of 35.1% in infants in the recent GAS study.^{15; 16}

Based on our results, SA allowed for the avoidance of IV and inhaled anesthetics in the majority of the infants, but in patients where SA was the planned anesthetic, 35.8% of infants ultimately required some supplementation. While 3.7% of the SA patients needed GA due to inadequate analgesic level, and an additional 3.2% needed inhaled anesthesia after the initial spinal block, the vast majority still avoided airway manipulation and the associated risks. The rate of supplementation however was greater than the 24.1% previously found in the overall infant spinal cohort at UVMMC, likely due to the stimulating nature of the pyloromyotomy procedure and increased duration of the surgery.¹⁴ The need for supplemental IV or mask anesthesia during pyloromyotomy is an important consideration, as these infants are known to have larger gastric volumes than the general pediatric surgical population.²⁴ Two episodes of vomiting under SA were recorded, but neither resulted in aspiration or increased length of stay. In performing SA in infants, skill and experience aid in safe intraoperative management. In infants receiving pyloromyotomy under SA, the brief increased surgical stimulation when the pylorus is being exteriorized requires additional vigilance, with initial management involving soothing the infant and a small amount of sucrose solution on a pacifier, and cautious use of IV sedation only when that fails.

In assessing resource utilization, OR times were faster and postoperative LOS shorter for SA compared to GA. The limitation of inter-institutional variation however must be considered, particularly the possibility of differences in the speed of surgeons, institutional logistics, nursing teams, and safety culture. Since specific surgical times were not available, we could not determine whether faster OR times were due to less time required for the surgery or the anesthesia. However in comparing the UVM failed SA patients who received GA with sevoflurane to the CUMC GA patients who received sevoflurane, the anesthetic exposure times were very similar, suggesting similar surgical times when GA is used. Also in the 8 UVM patients who had GA as the anesthetic of choice and were excluded from analysis, the mean OR time was found to be 99.5 ± 32.6 minutes, which was comparable to the GA patients at CUMC, but longer than the SA patients at UVM. This finding that shorter OR times occur in SA is supported by Kachko et al. who evaluated 60 infants undergoing pyloromyotomy in another observational study, finding that the 24 infants with SA had shorter OR times primarily due to a reduction in wake-up times.²⁵ While tetracaine was primarily used in our cohort, they reported success with similar doses of isobaric bupivacaine. Documentation may also differ between institutions, however in order to reduce the impact of differential reporting, we only included significant adverse events that would likely show up on the medical and anesthetic record. Differences between institutions including re-feeding protocols or discharge criteria which may impact LOS are also limitations of this study.

Our findings show that SA performed in a group of infants undergoing pyloromyotomy is associated with shorter OR times, shorter postoperative LOS, no differences in AE rates, and a decreased exposure to IV and inhaled anesthetics, although a significant percentage of SA infants still required supplemental anesthetic agents. While the long-term clinical benefits of these differences are still unclear, and further studies are needed to determine the risk of rare AEs such as aspiration, SA may offer a viable and safe alternative to GA for infant pyloromyotomy.

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Table 1
List of Adverse Events

Category	Adverse Event Description
Major	Cardiac arrest/chest compressions
	Systemic hypotension or bradycardia (requiring unanticipated ongoing cardiovascular support)
	Unanticipated injury related to anesthesia resulting in neurologic symptoms
	Blood transfusion event
	Soft tissue, muscle, or bone injury requiring ongoing treatment
	Wrong procedure or wrong sided surgery
	Other injury (anaphylaxis, malignant hyperthermia)
	Medication error or reaction
	Perioperative death
Respiratory	Aspiration
	Unanticipated apnea requiring intervention
	Pneumothorax
	Pulmonary edema
	Reintubation
	Unanticipated difficult intubation (endotracheal tube placement requiring >3 attempts)
	Unable to intubate
	Airway injury or eye injury requiring ongoing care
	Bronchospasm or laryngospasm requiring drug intervention
Regional	Block abandoned (unable to place)
	Block failed (unable to achieve adequate analgesic level)
	Catheter problem (occluded/kinked/dislodged)
	High spinal
	Hematoma at site of regional anesthesia
	Infection at site of regional anesthesia
	Positive test dose
	Unintentional unilateral block
	Unplanned dural puncture
	Inadvertent vascular puncture (blood aspirated)

Table 2
Demographic and Clinical Data

	Spinal Anesthesia(n=218)	General Anesthesia(n=206)
	mean $\pm$ SD	mean $\pm$ SD
Mean Age (days)	39.3 $\pm$ 17.7	40.4 $\pm$ 19.5
Weight (kg)	3.93 $\pm$ 0.73	4.03 $\pm$ 0.79
Preoperative Lab Values (mmol/L)		
Sodium	138.1 $\pm$ 2.9	137.8 $\pm$ 2.8
Chloride	103.1 $\pm$ 6.2	104.1 $\pm$ 4.9
Potassium	4.9 $\pm$ 0.8	4.7 $\pm$ 0.6
	n (%)	n (%)
Gender		
Girls	39 (17.9)	39 (18.9)
Boys	179 (82.1)	167 (81.1)
Gestational Age		
37 weeks	194 (89)	180 (87.4)
<37 weeks	24 (11)	26 (12.6)
ASA		
1	78 (35.8)	32 (15.5)
2	130 (59.6)	133 (64.6)
3	10 (4.6)	34 (16.5)
4	0 (0)	7 (3.4)
Surgical Technique		
Open	218 (100)	97 (47.1)
Laparoscopic	0 (0)	109 (52.9)

Table 3
Adverse Events in Spinal vs. General Anesthesia

	Spinal Anesthesia (n=218)	General Anesthesia (n=206)	p-value
Difficult intubation	-	13	
Broncho/Laryngospasm	1	1	
Apnea	1	2	
Block Failed	4	-	
Block Abandoned	4	-	
High Spinal	1	-	
Total AEs	11	16	
Total Number of Infants with AE	11	16	
Percentage of Infants with AE	5	7.8	0.3
<i>Excluding failed/abandoned spinals and multiple attempts at intubation</i>			
Total Number of Infants with AE	3	4	
Percentage of Infants with AE	1.4	1.9	0.6

Table 4
Resource Utilization: Operating Room Time and Postoperative Length of Stay

	Crude Estimate (95% CI)	p-value	Adjusted Estimate ^I (95% CI)	p-value
Additional Operating Room Time (minutes)				
GA compared to SA (all patients)	18.8 (14.9 – 22.6)	<0.0001	17.5 (13.5 – 21.4)	<0.0001
GA compared to SA (open procedures only)	16.0 (11.3 – 20.7)	<0.0001	14.0 (9.2 – 18.8)	<0.0001
GA compared to SA (open procedures and ASA<3 only)	14.8 (10.2 – 19.4)	<0.0001	14.9 (10.3 – 19.6)	<0.0001
Postoperative LOS (rate ratios)				
GA compared to SA (all patients)	1.29 (1.10 – 1.51)	0.002	1.19 (1.01 – 1.40)	0.04
GA compared to SA (open procedures only)	1.26 (1.04 – 1.53)	0.02	1.43 (1.19 – 1.72)	0.0002
GA compared to SA (open procedures and ASA<3 only)	1.27 (1.03 – 1.58)	0.03	1.27 (1.03 – 1.58)	0.03

GA = General Anesthesia, SA = Spinal Anesthesia, LOS = Length of Stay

^I Adjusted for gender, age at time of procedure, ASA 3, and gestational age <37 weeks in (all patients) and (open procedures only). Adjusted for gender, age at time of procedure, and gestational age <37 weeks in (open procedures and ASA<3).