Hypotheses: Use of spinal anesthesia is safe and effective in an outpatient population of preterm infants undergoing inguinal hernia repair (IHR) and eliminates routine postoperative hospital admission for apnea monitoring.

Methods: From October 1982 through October 1997, all preterm (gestational age [GA], ≤37 weeks), high-risk (preterm infants whose postconceptual age at surgery [PCAS] is ≤60 weeks) infants undergoing IHR with spinal anesthesia were studied prospectively. No exclusions were made for preexisting conditions. Elective IHRs and incarcerated hernias were both considered. A postoperative apnea rate was calculated and compared with published postoperative apnea rates in preterm infants after receiving general anesthesia.

Results: For 269 IHRs performed, 262 spinal anesthetic placements (97.3%) were successful in 259 infants; 246 placements were achieved on the first attempt and 16 on the second. The mean GA was 32 weeks (GA range, 24-37 weeks); mean PCAS, 43.7 weeks (PCAS range, 33.4-59.3 weeks); and mean birth weight, 1688 g (weight range, 540-3950 g). Two hundred six patients (78.6%) did not require supplemental anesthesia; 56 (21.4%) did: 34 received intravenous anesthesia; 6, general; 12, local; and 4, other regional. One hundred thirty-three infants had a history of apnea. Thirteen episodes of apnea were noted in 13 infants (4.9%) following the 262 procedures; all 13 were inpatients undergoing concomitant therapy for apnea (mean GA, 28 weeks; PCAS, 42.9 weeks). Four of these infants received supplemental anesthesia. This apnea rate is significantly lower than the published rate (10%-30%) (P = .01). One hundred three infants underwent IHR on an outpatient basis, 39 of whom had a history of apnea. None of these developed apnea postoperatively. The mean birth weight of this group was 2091 g (weight range, 710-3693 g); mean GA, 33 weeks (GA range, 25-37 weeks); and mean PCAS, 44.3 weeks (PCAS range, 35.4-59.2 weeks). All 103 patients were discharged home the day of surgery. Average time from room entry to incision was 26.3 minutes, which is similar to anesthesia induction time for patients receiving general anesthesia. Average time from bandaging to leaving room was 1 minute, less than usual time for patients receiving general anesthesia.

Conclusions: Spinal anesthesia is safe, effective, and eliminates the need for postoperative hospital admission in an outpatient population of preterm infants undergoing IHR. This results in considerable cost savings without compromising quality of care.


Inguinal hernias are common in preterm infants, occurring in up to 38% of infants whose birth weight is between 751 g and 1000 g and in 16% of those whose birth weight is between 1001 g and 1250 g. Because infants with inguinal hernia face a relatively high risk of incarcerated hernia and bowel obstruction, preterm infants undergoing inguinal hernia repair (IHR) shortly after becoming medically stable. Most pediatric surgeons perform these IHRs with general anesthesia. Multiple studies have demonstrated that preterm (gestational age [GA], ≤37 weeks), high-risk (preterm infants whose postconceptual age at surgery [PCAS] is <60 weeks) infants are at high risk of postoperative apnea. This high incidence of apnea has resulted in the routine hospital admission of infants after receiving general anesthesia for IHR to monitor for postoperative apnea.

Since 1977, our institution has been using spinal anesthesia on patients younger than 1 year undergoing surgery below the umbilicus. Abajian et al published their experience with 78 infants who received spinal anesthesia for various surgical procedures, 36 of whom were preterm and high risk. This study reported no incidence of apnea in infants who received spinal anesthesia. In a prospective study of 136 preterm infants younger than 60 weeks PCAS who received spinal anesthesia for various surgical procedures, Sartorelli et al demonstrated a postoperative apnea...
PATIENTS, MATERIALS, AND METHODS

During a 15-year period (October 1982 through October 1997), all preterm, high-risk infants at our institution undergoing IHR with spinal anesthesia, or infants who had undergone attempted spinal anesthetic placement for IHR, were included in this study. No patients were excluded for methylxanthine use or any preexisting conditions, such as cardiac, neurological, or respiratory anomalies. All patients were prospectively studied, and the information pertaining to the infant's medical histories (technical data regarding the surgery, operating times, operating room treatments [need for administration of medications or need for airway control by intubation], and postoperative follow-up) was gathered and placed into a database.

All patients underwent surgery at a single institution (Fletcher Allen Healthcare/University of Vermont Hospital, Burlington). All patients in the study were scheduled to undergo IHR, including elective unilateral and bilateral repairs and emergent incarcerated hernia repairs. In addition, some patients also underwent circumcisions at the same time. Informed consent for the administration of spinal anesthesia was obtained prior to surgery from patients’ parents. Use of spinal anesthesia was attempted in all patients. This study included inpatients, day of surgery admission patients (DOSA), and outpatients. All patients were monitored postoperatively for apnea and bradycardia. Apnea/bradycardia monitors were used for most inpatients and some outpatients for 24 to 48 hours postoperatively. Apnea was defined as cessation of respiration for 20 seconds or longer, while bradycardia was defined as a pulse less than 80 beats per minute for at least 20 seconds. Outpatients were observed in the post-anesthesia care unit prior to discharge and had their oxygen saturation monitored. All inpatient apneic or bradycardiac events were responded to appropriately and recorded. Infants were followed up by the attending surgeon (D.W.V.), either in his office within 2 weeks or in the hospital postoperatively. Parents of outpatients were specifically questioned about any witnessed apnea episodes.

The lumbar puncture was accomplished with a standard spinal anesthesia tray as described by Abajian et al.12 A hyperbaric solution was made with 0.5 mg/kg of 1% tetracaine hydrochloride mixed with an equivalent amount of 10% dextrose in a 1-mL syringe. If the procedure was expected to last longer than 30 minutes, 0.02 mL of 1:1000 epinephrine bitartrate solution was added to the syringe. Electrocardiographs and temperature and blood pressure monitors were all attached to the patient prior to positioning the patient in the lateral decubitus or sitting posture with the chin extended. The infant’s back was cleansed with iodophor solution, and a skin wheel was raised using 1% procaine. A 22- or 23-gauge disposable stilette spinal needle was used to perform the lumbar puncture at the most readily palpable interspace below the third lumbar vertebra. Once free flow of cerebrospinal fluid was obtained, the tetracaine-dextrose solution was administered. There was no attempt to aspirate the cerebrospinal fluid.

The infants were monitored for cessation of lower extremity movement, which occurred usually within 2 minutes. At that time, the patients had a lower extremity intravenous (IV) needle placed. A pinch was used to determine the sensory level of the patient while receiving anesthesia. Infants were comforted by the anesthesiologists during the procedure to prevent excessive upper extremity motion and were given a 10% glucose solution by bottle if they seemed hungry.

A review of all of the literature was performed to obtain published apnea rates in preterm, high-risk infants after receiving general anesthesia for IHR.4-11 We then compared our overall apnea episodes with the published data using binomial comparison.

RESULTS

For 269 IHRs, 262 spinal anesthetic placements were successful in 259 infants. One hundred thirty of these IHRs were previously reported by Sartorelli et al.13 Seven IHRs were started with the patient receiving other regional or general anesthesia; these 7 cases were not considered for further evaluation in our study. Three of 259 infants underwent 2 procedures; 1 experienced apnea following reoperation. This apnea episode was counted once since the procedures were more than 2 days apart, and the infant had no episodes of apnea during the time between the 2 procedures. A summary of the data for all infants participating in this study is given in Table 1. The mean GA of all infants included in the study was 32 weeks (GA range, 24-37 weeks); mean birth weight, 1688 g (weight range, 540-3950 g); mean PCAS, 43.7 weeks (PCAS range, 33.4-59.3 weeks); and mean weight at time of surgery, 3418 g (weight range, 1360-7103 g). The mean dose of tetracaine hydrochloride administered was 0.57 mg/kg (dose range, 0.25-1.40 mg/kg). One hundred fifty-four procedures were performed on infants who had a history of apnea. Apnea/bradycardia monitors were used for 117 inpatients and 6 outpatients. One hundred three outpatient, 149 inpatient, and 10 DOSA procedures were performed. Twenty-one infants had a history of congenital heart anomalies.

Adequate spinal anesthetic level was obtained following the first dose of tetracaine in 246 (91.4%) of 269 procedures (Table 2). An additional 17 patients underwent attempted placement of a repeated dose of spinal anesthetic, successful in 16. Therefore, 262 (97.3%) of 269 procedures were started with the patient receiving spinal anesthesia. The mean elapsed time between the infant entering the operating room to an incision being made was 26 minutes (time range, 14-50 minutes); this includes all failed or repeated spinal anesthetic administration.

Supplemental anesthesia was not necessary for 206 (78.6%) of 262 procedures (Table 2) and was necessary for 56 procedures (21.4%). Intravenous supplementa-
of spinal anesthesia was 151 minutes (time range, 45-250 minutes), while the mean operating time was 48 minutes (time range, 15-130 minutes). The infants usually remained in the operating room following application of the bandage for less than 1 minute.

Two hundred forty seven procedures were performed with no serious intraoperative events (Table 2). Of 8 infants with high spinals, none required intubation. Four infants experienced bradycardia in the operating room; 2 of these infants received vagolytics. One infant vomited and another was reported to have malperfusion. There were no reported episodes of oxygen desaturation, although 1 infant was reported to have a perioperative episode of apnea on transport after surgery.

Operating room treatments were not required for 222 procedures (Table 2). Five patients required vagolytics, and 6 required supplemental oxygen by blow-by. No fluid bolus or vasopressors were required by any infant. Sedation was administered during 26 procedures, and 3 infants had “other” treatments documented on their data form. One of these 3 received midazolam and local anesthetic, while a second was given nitrous oxide supplementation during the surgery. The third patient was an infant from the neonatal intensive care unit who suffered severe bronchopulmonary dysplasia and was oxygen dependent at the time of surgery. In the operating room, the patient experienced bradycardia and was treated with vagolytics. On transport back to the neonatal intensive care unit following surgery, he was noted to be “fussy” and was given midazolam. Shortly thereafter, he became bradycardic and apneic, requiring resuscitation and intubation (GA, 26 weeks; PCAS, 40.7 weeks; birth weight, 966 g; and weight at surgery, 2075 g).

Eight patients experienced bradycardia following IHR. All were inpatients and the episodes were self-limiting; bradycardia resolved without intervention. Thirteen patients experienced at least 1 episode of apnea at some point during their postoperative hospitalization, including the case of perioperative respiratory arrest. All patients who experienced apnea were inpatients who had a fairly extensive hospital course prior to IHR and were undergoing concomitant treatment for apnea at the time of surgery. Two of these 13 required IV anesthesia supplementation, and 2 received general anesthesia for supplementation.

The mean birth weight of the 13 patients who experienced apneic episodes postoperatively was 1006 g (weight range, 540-1420 g) (Table 3). Their mean GA was 28 weeks (GA range, 24-34 weeks); mean PCAS, 42.9 weeks (PCAS range, 35.0-51.0 weeks); mean tetracaine hydrochloride dose, 0.66 mg/kg (dose range, 0.39 to

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**Table 1. Data Summary for All Infants Entered in Study**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedures (N = 262)</td>
<td></td>
</tr>
<tr>
<td>Attempted placement of spinal anesthetic</td>
<td>269 (102.7)</td>
</tr>
<tr>
<td>Inpatient procedures</td>
<td>149 (56.9)</td>
</tr>
<tr>
<td>Outpatient procedures</td>
<td>103 (39.3)</td>
</tr>
<tr>
<td>DOSA procedure</td>
<td>10 (3.9)</td>
</tr>
<tr>
<td>Procedures on patients with apnea history</td>
<td>154 (58.7)</td>
</tr>
<tr>
<td>Followed with apnea/bradycardia monitor</td>
<td>123 (46.9)</td>
</tr>
<tr>
<td>Congenital heart anomalies</td>
<td>21 (8.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td></td>
</tr>
<tr>
<td>Gestational age, wk</td>
<td>32 (12-37)</td>
</tr>
<tr>
<td>Postconceptual age, wk</td>
<td>43.7 (33.4-59.3)</td>
</tr>
<tr>
<td>Birth weight, g</td>
<td>1688 (540-3950)</td>
</tr>
<tr>
<td>Weight at surgery, g</td>
<td>3417.9 (1360-7103)</td>
</tr>
<tr>
<td>Tetracaine hydrochloride dose, mg/kg</td>
<td>0.57 (0.25-1.40)</td>
</tr>
</tbody>
</table>

* DOSA indicates day of surgery admission.
† No. of patients, 259.

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**Table 2. Results of Spinal Anesthesia for Inguinal Hernia Repairs**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No. of procedures</td>
<td>269</td>
</tr>
<tr>
<td>Adequate spinal anesthesia administration, first dose</td>
<td>246 (91.4)</td>
</tr>
<tr>
<td>Repeated spinal anesthesia administration</td>
<td>17 (6.3)</td>
</tr>
<tr>
<td>Successful repeated spinal anesthesia administration</td>
<td>16 (6.0)</td>
</tr>
<tr>
<td>Procedures started with spinal anesthesia</td>
<td>262 (97.3)</td>
</tr>
<tr>
<td>Supplemental anesthetics</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>206 (78.6)</td>
</tr>
<tr>
<td>Intravenous</td>
<td>34 (12.9)</td>
</tr>
<tr>
<td>Local</td>
<td>12 (4.5)</td>
</tr>
<tr>
<td>General</td>
<td>6 (2.2)</td>
</tr>
<tr>
<td>Epidural</td>
<td>3 (1.1)</td>
</tr>
<tr>
<td>Caudal</td>
<td>1 (0.3)</td>
</tr>
<tr>
<td>Intraoperative events</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>205 (78.2)</td>
</tr>
<tr>
<td>Fussy infant</td>
<td>42 (16.0)</td>
</tr>
<tr>
<td>High spinal (no intubation)</td>
<td>8 (3.0)</td>
</tr>
<tr>
<td>High spinal (intubation)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Bradycardia</td>
<td>4 (1.5)</td>
</tr>
<tr>
<td>Vomiting</td>
<td>1 (0.3)</td>
</tr>
<tr>
<td>Malperfusion</td>
<td>1 (0.3)</td>
</tr>
<tr>
<td>Oxygen desaturation</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Apnea</td>
<td>1 (0.3)</td>
</tr>
<tr>
<td>Operative treatments</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>222 (84.7)</td>
</tr>
<tr>
<td>Vagolytics</td>
<td>5 (1.9)</td>
</tr>
<tr>
<td>Supplemental oxygen</td>
<td>6 (2.2)</td>
</tr>
<tr>
<td>Sedation</td>
<td>26 (9.9)</td>
</tr>
<tr>
<td>Other†</td>
<td>3 (1.1)</td>
</tr>
</tbody>
</table>

* Mean (range) time before incision, 26 minutes (14-50 minutes); duration of anesthesia, 151 minutes (45-250 minutes); and operative time, 48 minutes (15-130 minutes).
† See the “Results” section.

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**Table 3. Characteristics of Infants With Apnea Episodes**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight, g</td>
<td>1006 (540-1420)</td>
</tr>
<tr>
<td>Tetracaine hydrochloride dose, mg/kg</td>
<td>0.66 (0.39-1.13)</td>
</tr>
<tr>
<td>Weight at surgery, g</td>
<td>2336 (1840-3310)</td>
</tr>
<tr>
<td>Gestational age, wk</td>
<td>28 (24-34)</td>
</tr>
<tr>
<td>PCAS, wk</td>
<td>42.9 (35.0-51.0)</td>
</tr>
</tbody>
</table>

* Thirteen (4.9%) of 262; all 13 had a history of apnea. The apnea rate minus the procedures using general anesthesia is 11 (4.2%) of 256. PCAS indicates postconceptual age at surgery.
1.13 mg/kg; and mean weight at time of surgery, 2335 g (weight range, 1840 to 3310 g). The overall apnea rate following 262 attempted inguinal herniorrhaphies with spinal anesthetic was 4.9% (13/262). Eliminating the 6 procedures requiring general anesthetic supplementation, the apnea rate drops to 4.2% (11/256). One hundred eight of these high-risk, preterm infants had no history of apnea, and none experienced apnea postoperatively. There were no deaths in our inpatient population.

During the past 15 years, our institution has performed few IHR with general anesthesia on preterm infants, so we compared our rates of apnea in preterm infants after receiving spinal anesthesia with rates of apnea reported in the literature in preterm infants after receiving general anesthesia. We found 8 studies that examined apnea rates in preterm infants after receiving general anesthesia undergoing surgery with a PCAS younger than 60 weeks.

There is no consensus on an exact apnea rate in preterm infants after receiving general anesthesia. Some studies either do not give the exact definition of apnea or define it as cessation of breathing for 15 seconds or longer. We chose to define apnea as cessation of breathing for at least 20 seconds, which appears to be the more commonly accepted definition in the literature. While there is no accepted exact rate for true 20-second apnea, most will agree that it is likely between 10% to 30% in this high-risk population. After review of these studies, we feel that an overall apnea rate of 10% following general anesthesia for IHR in preterm, high-risk infants is a conservative estimate. An analysis of our apnea rate (4.9%; 99% confidence interval, 2.2-9.5) following IHR with spinal anesthesia in this population was significantly lower than the conservative estimate of 10% from the literature.

There were 103 outpatients participating in this study who underwent 103 procedures. Data on this group are summarized in Table 4. Thirty-nine of these patients had a history of apnea, and 7 had a history of congenital heart problems. The mean GA of this group was 33 weeks (GA range, 25-37 weeks); mean PCAS, 44.4 weeks (PCAS range, 35.4-59.3 weeks); mean birth weight, 2091 g (weight range, 1840 to 3310 g); mean weight at time of surgery, 4061 g (weight range, 1818-7000 g); and mean dose of tetracaine hydrochloride administered, 0.53 mg/kg (dose range, 0.39 to 0.91 mg/kg).

Ninety-seven patients received adequate spinal anesthesia following the first dose, while 6 patients needed a repeated administration of spinal anesthesia. Eighty-three patients needed no anesthetic supplementation, while 17 patients received IV supplementation. An additional 3 infants required local anesthesia. Seventy-two infants in the outpatient group were noted to have no intraoperative events. Twenty patients were classified as being “fussy.” There were no cases of apnea in this group, and 2 patients did experience an episode of bradycardia. In 1 case, a decreased heart rate occurred, which was successfully treated with atropine sulfate and blow-by oxygen. The remainder of this patient’s course was uneventful, and the patient did not have a history of apnea and/or bradycardia. In the second case, a short episode of bradycardia was witnessed, which resolved spontaneously, and no treatment was instituted. This patient did have a history of apnea and/or bradycardia. Eight patients were reported to have had a high spinal; none required intubation. One case of malperfusion was reported, which resolved spontaneously.

Twenty-two of 103 infants had intraoperative treatments instituted at some point during IHR. Four patients received vagolytics, while 14 required IV sedation. An additional 4 patients also received supplemental oxygen by blow-by. No patients required either vasopressors or fluid boluses.

All outpatients were discharged home following a 1- to 6-hour stay in the postanesthesia care unit. All were followed up in the attending surgeon’s office within 1 week. There were no reported episodes of apnea following discharge. Table 5 gives the increasing number of outpatients undergoing IHR at our institution. There was no mortality in this group and no morbidity directly related to the anesthetic. Table 6 gives data on all our inpatients and DOSA patients to allow comparison to the

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**Table 4. Characteristics of Outpatients Undergoing Inguinal Hernia Repairs With Spinal Anesthesia**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total procedures and outpatients</td>
<td>103 (100)</td>
</tr>
<tr>
<td>History of apnea</td>
<td>39 (37.8)</td>
</tr>
<tr>
<td>Congenital heart problems</td>
<td>15 (14.5)</td>
</tr>
<tr>
<td>Adequate spinal anesthesia administration, first dose</td>
<td>97 (94.1)</td>
</tr>
<tr>
<td>Repeated spinal anesthesia administration†</td>
<td>6 (5.9)</td>
</tr>
<tr>
<td>Supplemental anesthesia</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>83 (80.5)</td>
</tr>
<tr>
<td>Intravenous</td>
<td>17 (16.5)</td>
</tr>
<tr>
<td>Local</td>
<td>3 (2.9)</td>
</tr>
<tr>
<td>Intraoperative events</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>72 (69.9)</td>
</tr>
<tr>
<td>Fussy infant</td>
<td>20 (19.4)</td>
</tr>
<tr>
<td>Bradycardia</td>
<td>2 (1.9)</td>
</tr>
<tr>
<td>Apnea</td>
<td>0 (0)</td>
</tr>
<tr>
<td>High spinal (no intubation)</td>
<td>8 (7.7)</td>
</tr>
<tr>
<td>High spinal (intubation)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Malperfusion</td>
<td>1 (0.9)</td>
</tr>
<tr>
<td>Intraoperative treatments</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>81 (78.6)</td>
</tr>
<tr>
<td>Vagolytics</td>
<td>4 (3.8)</td>
</tr>
<tr>
<td>Sedation</td>
<td>14 (13.5)</td>
</tr>
<tr>
<td>Vasopressors</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Fluid bolus</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Supplemental oxygen</td>
<td>4 (3.8)</td>
</tr>
<tr>
<td>Other</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

†All successful.

**Table 5. Outpatient Inguinal Hernia Repairs**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Total No. of Patients</th>
<th>No. (%) of Outpatients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 1982-Oct 1987</td>
<td>60</td>
<td>4 (6.6)</td>
</tr>
<tr>
<td>Nov 1987-Oct 1992</td>
<td>94</td>
<td>42 (44.6)</td>
</tr>
<tr>
<td>Nov 1992-Oct 1997</td>
<td>108</td>
<td>57 (52.7)</td>
</tr>
</tbody>
</table>

*Mean (range) gestational age, 33 weeks (25-37 weeks); postconceptual age at surgery, 44.4 weeks (35.4-59.3 weeks); birth weight, 2091 g (710-3693 g); weight at surgery, 4061 g (1818-7000 g); and tetracaine hydrochloride dose, 0.53 mg/kg (0.39-0.91 mg/kg).
The number of preterm infants who present with inguinal hernias has increased with advances in neonatal care. Peevy et al10 found the incidence of inguinal hernias to be higher than 30% in infants with birth weights less than 1000 g. Early repair has been advocated owing to the high risk of incarcerated hernia and associated complications.2 A survey by the Section on Surgery of the American Academy of Pediatrics3 found that general anesthesia was used by 70% of the pediatric surgeons polled to perform IHR in high-risk infants. If the surgery was to be performed in an outpatient setting, 69% of surgeons delay the procedure until a PCAS of at least 50 weeks. An additional 15% of surgeons never perform IHRs on an outpatient basis.3

The risk of apnea in preterm infants receiving general anesthesia has been investigated by numerous reports in the literature.4-11 Numerous factors have been implicated as the cause of apnea in preterm infants, including airway obstruction, anemia, diminished respiratory drive, hypothermia, diaphragmatic fatigue, and residual effects of anesthetics.6,14-17 While there is no consensus on the exact incidence of apnea in preterm infants who receive general anesthesia, the rate is likely between 10% to 30%. This has made the routine hospital admission of preterm infants after undergoing IHR with general anesthesia the delay of repair necessary, as evidenced by the American Academy of Pediatrics survey.3

A study by Abajian et al12 in 1984 sparked an interest in spinal anesthesia as an alternative to general anesthesia in this high-risk population. Since that time, numerous other studies have been published examining the risk of apnea in preterm infants after receiving spinal anesthesia.13,18,19 Veverka et al18 described 84 preterm, high-risk infants who underwent IHR with spinal anesthesia with no episodes of apnea. Webster et al19 reported that 5 infants of 44 who had received spinal anesthesia for IHR had apneic episodes. However, all 5 infants had received supplemental inhalation anesthesia. Sartorelli et al13 prospectively evaluated 136 preterm, high-risk infants who underwent various surgical procedures, 130 of which were inguinal herniorrhaphies. One patient (0.8%) experienced apnea postoperatively. This study led directly to the routine use of spinal anesthesia for outpatients in this high-risk population at our institution.

Our study builds on the work of Sartorelli et al. We have now prospectively studied 259 preterm, high-risk infants who underwent IHR with spinal anesthesia. To our knowledge, this is the largest reported series of IHRs using spinal anesthesia in this population. This also includes the largest reported series of outpatient IHRs in preterm infants receiving spinal anesthesia. Analysis of this study demonstrates that the risk of apnea in preterm infants after receiving spinal anesthesia is significantly lower than reported apnea rates in preterm infants after receiving general anesthesia.

All infants experiencing an apneic episode after receiving spinal anesthesia in our study were inpatients with a recent history of apnea who were undergoing concomitant therapy for apnea at the time of surgery. None of the outpatients were observed to have an apneic episode, and this group included 39 infants with a history of apnea. No outpatients received general anesthetic supplementation for their surgery, and none were actively experiencing apneic episodes while at home prior to surgery. This would suggest that preterm, high-risk infants who are medically ready to be at home are at little or no increased risk of experiencing apnea postoperatively after receiving spinal anesthesia for IHR. Thus, using spinal anesthesia eliminates routine overnight hospital admission in this population for apnea monitoring, assuming general anesthetic supplementation was not required, and reduces the stress imposed on the family. There is little if any additional cost incurred during the procedure from the use of spinal anesthesia compared with general anesthesia. Any additional operating room time at the beginning of the procedure is usually made up for at the end of the procedure since no time is spent waiting to extubate the infant. However, the elimination of routine overnight hospital admission for preterm infants after receiving general anesthesia provides the most considerable overall cost savings at our institution.

A recent editorial in a newsletter from the Society for Pediatric Anesthesia supported the routine use of general anesthesia for repair of asymptomatic inguinal hernia in medically stable, preterm infants.20 The arguments proposed were as follows:

- The effectiveness of regional anesthesia in preventing postoperative apnea remains inconclusive.
- Regional anesthesia is technically difficult and not reliable in prematurely born infants.
- The flexibility, technical ease, and reliability of general anesthesia makes it cost effective (improved economic outcome).

Our experience with spinal anesthesia in this population refutes each of these claims.

Our data demonstrate that the risk of apnea in preterm infants after receiving spinal anesthesia is significantly lower than the apnea rate in preterm infants after receiving general anesthesia. Our low apnea rate was in accord with multiple other smaller studies.12,13,18,19 In addition, the only infants who experienced apnea in our study were those who were hospitalized at the time of their surgery and undergoing therapy and monitoring for apnea. None of our 103 outpatients reported any apnea following surgery with spinal anesthesia. All were discharged home. Spinal anesthesia clearly reduces the overall risk of anesthetic-associated apnea in preterm, high-risk infants.
risk infants undergoing IHR and likely eliminates apnea in patients who have been discharged from the hospital and are stable at home prior to IHR.

Ninety-seven percent of our procedures were started with the patient receiving spinal anesthesia, and 206 patients (78.6%) did not require any anesthesia supplementation. Of the infants who received supplementation, 46 (82%) required either local or IV. If spinal anesthesia was inadequate and the patient was already prepared for surgery, it was up to the discretion of the anesthesiologist to administer IV sedation or general anesthesia for supplementation. The average duration of spinal anesthesia effectiveness was 3 times longer than the average operative time, thus allowing more than enough time to complete the IHR. In instances during which effective spinal anesthesia is not obtained, general anesthesia can be administered, and the surgeon may proceed with the understanding that the infant’s risk of apnea is now significant, and postoperative hospital admission is generally required for apnea monitoring. However, our complete spinal anesthesia failure rate (unable to begin procedure while patient is receiving spinal anesthesia) was 0% in our outpatient population (n = 103) and only 2.7% overall in the study.

Use of spinal anesthesia for IHR in preterm, high-risk infants is cost-effective at our institution. An increase in operating room time owing to the delay in starting surgery while waiting for spinal anesthesia administration is usually made up for at the end of the procedure since there is no need to wait until the infant awakes. In addition, since the study by Sartorelli et al, we routinely perform this procedure on an outpatient basis. We do not postpone the procedure until the infant is at an older PCAS, as is sometimes done to reduce the risk of apnea when general anesthesia is used on an outpatient basis. This reduces the risk of incarcerated hernia or associated complications that sometimes occur when surgery is postponed and at the same time eliminates routine postoperative hospital admission. With a minimum daily room and monitoring charge of $630 at our institution, use of spinal vs general anesthesia has resulted in a minimum reduction in charges of $64,890 for our 103 outpatients. This does not consider the financial strain as well as the emotional stress that is imposed on families in a rural state such as Vermont when a child is hospitalized far from home.

There are 2 areas in which this study may be criticized. The first is the lack of patient randomization between a general anesthesia control group and a spinal anesthesia test group, thereby requiring the use of historical controls. The second is the lack of home apnea monitoring following outpatient surgery, leading to possible underestimating of apneic episodes, although none of these episodes were of clinical significance.

The routine use of spinal anesthesia in preterm, high-risk infants at our institution for surgery below the umbilicus dates back to the early 1970s. Abajian et al suggested that spinal anesthesia reduces the risk of postoperative apnea in preterm, high-risk infants. We continue to use spinal anesthesia routinely for surgery below the umbilicus in infants and feel strongly that it reduces the risk of postoperative apnea in a high-risk population. Since we rarely plan IHRs with general anesthesia and have a high success rate in obtaining effective spinal anesthesia, a control group at our institution would require many years to accrue. As cited earlier, numerous prospective studies have reviewed the risk of apnea in preterm infants undergoing IHR. While there is no consensus on an exact apnea rate, we compared our apnea rate with the most conservative reasonable estimates cited in all of the literature.

Only a handful of our outpatients used apnea/bradycardia monitors at home following surgery. Prior work by Sartorelli et al on inpatients who were virtually all followed up with apnea/bradycardia monitors demonstrated that there was no increased risk of apnea in preterm infants after receiving spinal anesthesia for IHR if inhalation anesthetics were not required for supplementation. Since that time, we have routinely performed IHRs on an outpatient basis. There were no outpatients who underwent IHR with spinal anesthesia who were scheduled for a DOSA, and this included 15 infants who may be considered higher risk secondary to congenital heart anomalies. All outpatients had oxygen saturation monitoring while in the postanesthesia care unit prior to discharge. No apnea events were witnessed either in the postanesthesia care unit or at home, and no infant experienced any event requiring readmission or reevaluation in the emergency department following discharge. This cohort of outpatients is considered a high-risk group for postoperative apnea after receiving general anesthesia, as was our inpatient population in our earlier experiences. The fact that they did not have any episodes of respiratory compromise is owing to the anesthetic used for their surgery.

This study provides further evidence that spinal anesthesia is effective in reducing or eliminating the risk of postoperative apnea following IHR in high-risk inpatient and outpatient populations of preterm infants. We have also demonstrated that for IHRs, spinal anesthesia is technically feasible and successful in most infants for whom it is attempted. In addition, we have demonstrated that the use of spinal anesthesia eliminates the need for routine postoperative hospital admission after IHR in a high-risk, preterm population of outpatient infants. We use spinal anesthesia for nearly all IHRs for this population, and if the infant has been stable at home prior to surgery, then we feel comfortable discharging these infants home as long as supplemental inhalation anesthesia was not required. Spinal anesthesia is thus both safe and effective in an outpatient population of high-risk, preterm infants undergoing IHR and eliminates routine postoperative admission for apnea monitoring.


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1. Peavy KJ, Speed FA, Hoff CJ. Epidemiology of inguinal hernia in preterm neo-

2. Rescorla FJ, Gросfeld JL. Inguinal hernia repair in the perinatal period and en-

3. Weiner ES, Spigler AR, Rodgers BM, et al. Hernia survey of the Section on Sur-

4. Weidman DJ. Preterm infants are more prone to complications following minor
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5. Liu LMP, Cote CJ, Nishim G, et al. Life-threatening anaphylaxis in infants recover-

6. WELBORN LG, Ramirez N, Tae Hee Oh, et al. Postanesthetic anaphylaxis and peri-

7. Kurth GD, Touloukian RJ. Pediatric anesthesiologists, I have to tell you Dr Dibbins,
   we also have 4 pediatric surgeons who are used to doing a large amount of
   infants with hernias, I don’t think it’s applicable to the general
   population.

8. The message is that the baby who is medically ready to go home or who is medically
   ready to be at home can be done as an outpatient. One needs to know what the status of each
   infant is. I would like to ask Dr Vane what he does if the spinal
   cannot be done. What do you do about the baby? Do you then
   bring the baby into the hospital and try again the next day if you can get on the operating room schedule? Do you ever make
   a decision if you miss the spinal that it would be too much of a
   problem for the parents because they have already given up a
day of work to do this that you use a general anesthetic in the
   baby and put them to sleep?

**Donald Hight, MD, Hartford, Conn.** This study takes a
   tremendous relationship between the pediatric surgeons and your
   anesthesiologists. They have to know the surgeon as you do
   the anesthesiologist. There are some surgeons quite honestly
   who couldn’t do some of these large hernias within the
   time frame that a typical spinal anesthetic will afford. You’re
   operating within a significant time constraint. It’s not like a
   general anesthetic, which can go on for an extended period of time.
   I’d like to emphasize the fact that neonatal hernia repairs are
   a very highly specialized procedure. The success of this form of
   management involves a relationship between anesthesia and the
   pediatric surgeon in order to carry this out safely.

**Robert J. Touloukian, MD, New Haven, Conn.** My ques-
   tion has to do with the need for conversion to general anesthesia
   after an initial attempt at spinal either prior to begin-
   ning the operation or for a failed spinal during the course of the
   procedure. We believe it remains the surgeon’s responsi-
   bility to determine the adequate level of anesthesia needed to
   proceed with the operation. I noticed that there were very few
   conversions during the course of the procedure and the point,
   of course, is that the surgeon has to move along quickly to com-
   plete the case within the allotted time period. Would you com-
   ment on the issue of determining the adequate level of anes-
   thesia before beginning the case?

**Dr Vane:** The conversion rate is low. Essentially the ma-
   jority of the conversions are done prior to the operation being
   started. The routine length for the anesthetic is about 2 hours.
   The issue addressed by all of the surgeons is that you really prob-
   ably shouldn’t be tackling these cases unless you know what
   you’re doing in a premature infant. The hernias can be ex-
   tremely difficult to do. In this age group, it is common to do
   bilateral approaches, at least for us and if you’re taking more than
   an hour for the first side, I think you may want to abort
   and wait. I always do the most symptomatic side first and then
   subsequently can wait. I have not had to personally stop the
   case. My partner has in one situation. Converting is important
   if something goes wrong. You find something bizarre and that
   can be done, although I have to tell you that the conversion
   rate was higher in the early part of our study. We have only
   converted one in 10 years now that I’ve been at Vermont, so
   that’s going down dramatically with more experience.

As to who does the anesthesia, there is no question there has to
   be a technically adept surgeon, otherwise you’re going to be in
   a disaster if the spinal is wearing off and you’re still working
   on the first side and so again it should be probably reserved to
   the technically trained pediatric surgeons. However, for the an-
  esthesiologists, I have to tell you Dr Dibbins, we also have 4 ped-
  iatric anesthesiologists, but at night if a kid comes in, some-
times I’ll get stuck with an adult anesthesiologist, and it’s what
   they do. They just have to do it. I just don’t really tolerate them
   not putting a spinal in, and they over the course of time listen to
   the surgeon. Remember, medical students are doing spinal taps
   on these babies up in the neonatal intensive care unit, and so it’s
   not that hard. I do think adult anesthesiologists can do it.

Albert W. Dibbins, MD, Portland, Me. For the first time some-
one has been brave enough to take a group of premature in-

fants who have been successfully treated for apnea and say that
   spinal anesthesia will reduce the risk of postoperative apnea

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