Published in final edited form as:

J Child Neurol. 2012 July ; 27(7): 859–866. doi:10.1177/0883073811428378.

Effect of General Anesthesia in Patients With Cerebral Palsy at the Turn of the New Millennium: A Population-Based Study Evaluating Perioperative Outcome and Brief Overview of Anesthetic Implications of This Coexisting Disease

C. Thomas Wass, MD¹, Mary E. Warner, MD¹, Gregory A. Worrell, MD, PhD¹, Julie A. Castagno, CRNA¹, Melinda Howe, CRNA¹, Kimberly A. Kerber, CRNA¹, Jenna M. Palzkill, NA, CRNA¹, Darrell R. Schroeder, MS¹, and Gregory D. Cascino, MD¹

¹Mayo Clinic, Rochester, MN, USA

Abstract

The severity of preoperative cerebral palsy appears to correlate directly with postoperative complications. The primary aim of this study was to characterize the frequency of perioperative morbidity and mortality in cerebral palsy patients undergoing anesthesia. This was accomplished by undertaking a systematic review of the Mayo Database. The risk for perioperative adverse events was 63.1% (95% confidence interval 59.8%–66.5%). However, it deserves clarification that hypothermia and clinically significant yet non–life-threatening hypotension represented the majority (80%) of these complications. When these 2 events are excluded, the rate of adverse perioperative events was 13.1% (95% confidence interval 10.8%–15.5%). Risk factors associated with increased risk included American Society of Anesthesiologists physical status score exceeding 2, history of seizures, upper airway hypotonia, general surgery procedures, and adults. Our findings are useful to counsel patients with cerebral palsy, their caregivers, and their guardians regarding the risk of general anesthesia.

Keywords

cerebral palsy; general anesthesia; morbidity; outcome; perioperative

Cerebral palsy is a nonspecific term encompassing a constellation of symptoms ranging from mild monoplegia with normal cognitive capacity to spastic quadriplegia with severe

© The Author(s) 2012

Corresponding Author: C. Thomas Wass, MD, Department of Anesthesiology, Mayo Clinic, 200 First, Street SW, Rochester, MN 55905, wass.thomas@mayo.edu.

Author Contributions

All physician authors participated in research design, data interpretation, manuscript preparation, and supervising bringing the project to fruition. CTW was ultimately responsible for overseeing the entire research project whereas GDC served as our senior author who actively guided the team through the process. The 4 student nurse anesthetists were responsible for systematic review of medical records for data acquisition and entering this information into the research database. Our statistician was responsible for data analysis as well as table and figure preparation. Nobody cited in the authorship served as a “ghost author” or writing assistant.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

The study was conducted following Institutional Review Board approval. In compliance with Health Insurance Portability and Accountability Act guidelines, patients were identified through the Anesthesia Clinical Research Database, which contains perioperative information on patients who have undergone surgical procedures requiring general anesthesia.

mental retardation.¹ Others have encouraged the international research community to validate cerebral palsy definitions and classifications that are simple to use and yield reproducible results.² Yet, to date, we have neither an objective test that can be used as a screen nor a diagnostic test that can be used as a gold standard.² However, the common denominator is the presence of motor dysfunction arising from nonprogressive lesions or abnormalities in the brain sustained early in life.^{1,3–5} Anecdotally, the severity of preoperative cerebral palsy appears to correlate directly with postoperative complications. However, more definitive evidence is lacking as to whether these individuals are truly at increased perioperative risk for adverse events. The primary aim of this study was to characterize the frequency of perioperative morbidity and mortality in cerebral palsy patients undergoing general anesthesia.

Methods

The study was conducted following Institutional Review Board approval. The study population was restricted to cerebral palsy patients undergoing surgery (including elective or emergent) at Mayo Clinic, Rochester, Minnesota, between January 1, 1992, and December 31, 2008. In compliance with Health Insurance Portability and Accountability Act guidelines, patients were identified through the Anesthesia Clinical Research Database, which contains perioperative information in patients who have undergone surgical procedures requiring general anesthesia. The database was cross referenced with the International Classification of Diseases–9 codes for cerebral palsy, chronic global static encephalopathy, perinatal infarction, remote cerebral infarction, or neonatal stroke. To avoid selection bias, the patient cohort was not based on “pick and choose” inclusion criteria. For patients who underwent multiple procedures during the study period, only the first surgery was considered. Starting with the most recent surgery before December 31, 2008, a consecutive sample of 800 patients who underwent surgery prior to this date was selected in a sequential retroactive manner.

A systematic review of medical records (by professional abstractors such as physician anesthesiology consultants, certified registered nurse anesthetists, nurse anesthesia students, or Mayo’s Anesthesia Clinical Research Unit–registered nursing or respiratory therapy staff) was performed identifying the cerebral palsy diagnosis, demographic data, American Society of Anesthesiologists physical status classification (ie, American Society of Anesthesiologist score), comorbidities, operative procedure, current medications, anesthetic medications received during the procedure and any complications recorded during the perioperative period (defined as that time interval immediately preceding, during, and up to 24 hours following anesthesia end time). In addition to demographic data, abstracted information included a detailed history of common preoperative comorbid disease (eg, epilepsy, mental retardation, gastroesophageal reflux disease, malnutrition, history of aspiration or recurrent pneumonia, upper airway hypotonia, reactive airway disease, pneumonia), perioperative considerations (eg, increased secretions, difficult mechanical ventilation due to extrinsic restrictive lung physiology associated with scoliosis, pneumonia, reactive airway disease, aspiration), as well as events specific to the patients’ antispasmodic medications and anesthesia. More specifically, we also collected data pertaining to delayed emergence (awakening) and generalized or respiratory hypotonia.

Data Analysis

The primary outcome was the occurrence within 24 hours postoperatively of any of the following prespecified adverse perioperative events (airway obstruction, aspiration, bronchospasm, delayed emergence, hypotension, hypothermia, laryngospasm, neuropathy, pneumonia, reintubation, seizure, or stridor). The overall rate was estimated using a point estimate and corresponding 95% confidence interval. A sample-size of $N = 800$ was chosen

to ensure that the half-width of the 95% confidence interval would be less than 3.5%. In addition to describing the frequency of adverse events, exploratory analyses were performed using logistic regression to identify patient and procedural characteristics associated with perioperative adverse events. Both univariate and multivariate analyses were performed. In all cases, 2-tailed *P* values less than or equal to .05 were considered statistically significant.

Results

A total of 800 patients (457 male, 343 female) are included in this report. There were 517 (65%) pediatric patients and 283 (35%) adults. Seven hundred eighty-seven (98.4%) of the operations were elective whereas 13 (1.6%) were emergent.

There were 505 patients (63.1%, 95% confidence interval 59.8%–66.5%) who experienced 1 or more perioperative adverse events. The percentage of patients experiencing 1 or more event differed significantly ($P < .001$) across procedure types (76.9% orthopedic, 76.5% neurologic, 68.0% general surgery, 55.6% ear, nose, and throat, 48.0% gastrointestinal, 32.3% radiology, and 66.7% for other procedures) and was significantly higher for adults compared with pediatric patients (72.1% vs 58.2%; $P < .001$) and higher for males compared with females (66.3% vs 58.9%; $P = .03$). One death occurred within 24 hours because of unsuccessful resuscitation from cardiac arrest near the conclusion of posterior spine surgery wound closure.

The frequency of the specific adverse perioperative events is presented in Figure 1. The most frequently observed events were hypothermia (defined as a core temperature $< 35.5^{\circ}\text{C}$), which was documented in 441 (55.1%) patients, and hypotension (defined as a blood reduction 20% from baseline), which was documented in 120 (15.0%). The frequency of the other specific events included delayed emergence, 45 (5.6%); seizure, 19 (2.4%); airway obstruction, 17 (2.1%); pneumonia, 13 (1.6%); stridor, 7 (0.9%); bronchospasm, 6 (0.8%); neuropathy, 6 (0.8%); reintubation, 4 (0.5%); aspiration, 4 (0.5%); and laryngospasm, 4 (0.5%) (Figure 1).

Given the high frequency of hypothermia and hypotension, subsequent analyses were performed that excluded these events. There were 105 patients (13.1%, 95% confidence interval 10.8%–15.5%) who experienced 1 or more perioperative adverse events other than hypothermia or hypotension. A summary of analyses assessing characteristics potentially associated with these events is presented in Table 1. Patient characteristics found to be univariately associated with an increased risk for these events included older age ($P = .05$), higher American Society of Anesthesiologists physical status ($P < .001$), presence of feeding tube ($P = .003$), gastrointestinal reflux ($P = .01$), malnourished ($P = .005$), history of pneumonia (.001), reactive airway disease ($P = .01$), history of aspiration ($P = .002$), scoliosis ($P = .02$), history of seizures ($P = .01$), and upper airway hypotonia ($P < .001$). After backward elimination of nonsignificant variables, the characteristics found to be multivariately associated with these adverse perioperative events included age, type of procedure, American Society of Anesthesiologists physical status, history of seizures, and upper airway hypotonia (Table 2).

Discussion

In this retrospective analysis of pediatric and adult patients with cerebral palsy undergoing surgery, the risk of perioperative morbidity and mortality was 63% and 0.1%, respectively. Hypothermia and hypotension represented the vast majority (80%) of these complications. The majority of the individuals in this investigation were pediatric patients. As such, we observed a greater number of complications in pediatric patients when compared with

adults. However, as a percentage, adults were at greater risk of a perioperative complication (adults vs pediatrics: 72.1% vs 58.2%, $P < .001$). Other factors associated with increased risk for experiencing an adverse perioperative event included individuals with an American Society of Anesthesiologists physical status score exceeding 2, a history of seizures, and upper airway hypotonia as well as those undergoing general surgery procedures. Unfortunately, little comparative data exist to compare our complication rates with other general surgical populations.⁶

Cerebral Palsy Etiology and Epidemiology

In 1862, William Little, an orthopedic surgeon, postulated that peripartum asphyxia and birth trauma were 2 of the principle causes of cerebral palsy.⁶ Despite Sigmund Freud's opposing viewpoint that perturbations in antenatal intrauterine development were responsible for cerebral palsy, peripartum asphyxia was touted as the primary etiologic source for more than a century.⁶ Ironically, intrapartum hypoxia was recently estimated as the etiologic source in only 6% of all cerebral palsy patients.¹ As such, peripartum physicians are often erroneously implicated in medical litigation.⁶ For example, according to the American Society of Anesthesiologists Closed Claims Project database, obstetric anesthesia claims make up 12% of all anesthesia litigation (of these, 18% involve newborn brain injury), with a median payout exceeding \$1 million.⁶

In reality, the etiology is likely multifactorial and caused by perturbations, such as maldevelopment of the brain, perinatal stroke, prenatal infection (eg, toxoplasmosis, rubella, cytomegalovirus, herpes), genetic disorder, ischemic insult in utero (eg, uteroplacental insufficiency), or prematurity (making them vulnerable to intracranial hemorrhage).^{1,4,7-9}

Surgical Procedures

Epidemiologic surveys report the prevalence of cerebral palsy, in industrialized countries, is fairly static at approximately 2.5 per 1000 live births among normal birth weight babies.^{1,4,5,7} Considering the comorbidity known to accompany cerebral palsy, these individuals frequent the operating room for dental rehabilitation, Nissen fundoplication, feeding gastrostomy tube placement, tracheostomy, major spine surgery, neurosurgical procedures to control spasticity (eg, selective dorsal rhizotomy), as well as upper and lower extremity orthopedic surgery (eg, heel cord lengthening).^{1,3,5,10} In our study population, individuals undergoing general surgery procedures were at greatest risk (odds ratio 1.71) of experiencing a postoperative complication (Table 2) whereas those undergoing general anesthesia for radiologic (odds ratio 0.40) procedures incurred the lowest risk (Table 2). The latter may be due to radiologic procedures being often minimally invasive percutaneous procedures that take place in warmer environments (ie, not a frigid operating room) and are devoid of substantial blood loss or fluid shifts. Taken together, data gleaned from our investigation should better equip surgical care teams with pertinent information enabling them to better anticipate—and thus, avoid—perioperative complications specific to this subpopulation of patients.

Clinical Classification of Cerebral Palsy^{3-5,8}

- **Spastic:** Lesions in the cerebrum. It includes quadriplegia, diplegia, and hemiplegia. The number of extremities affected (and the degree of spasticity) correlates with the level of intelligence.
- **Dyskinetic:** Lesion in basal ganglia. It includes dystonia (twisting position of torso), athetosis (purposeless movements of extremities), and chorea (quick, jerky proximal movements of extremities).
- **Ataxic:** Lesion in cerebellum. It includes tremor, loss of balance, and speech.

- Mixed: Lesion in cerebrum and cerebellum. It includes spasticity and athetoid movements.

Perioperative Concerns Related to Cerebral Palsy

Respiratory—Children who have cerebral palsy often have an impaired ability to clear pharyngeal secretions which results in secretion pooling in the oropharynx.^{1,3–5,8} The etiology of copious oral secretions is a combination of hyperactive salivary glands coupled with impaired swallowing. As a result, managing the airway of these individuals can be quite difficult as oral secretions may preclude adequate mask ventilation or visualization of the glottis during tracheal intubation. Additionally, coexisting scoliosis can cause extrinsic restrictive lung physiology resulting in hypoxemia, pulmonary hypertension (in severe cases), as well as decreased ability to cough and clear secretions.^{1,3,5,8} In our study, we observed airway obstruction in 2.1%, pneumonia in 1.6%, stridor 0.9%, bronchospasm 0.8%, reintubation in 0.5%, and laryngospasm in 0.5% of our patients.

Cardiovascular—When one considers the perioperative implications of caring for cerebral palsy patients, cardiovascular compromise is not typically of great concern. Ironically, in the present study, we found cardiovascular complications to be the second most common perioperative event (Figure 1). In particular, we observed hypotension (defined as 20% decrease in systemic blood pressure when compared with a preoperative baseline value) in 15% of our patient population (Figure 1). The etiology for such an observation is likely multifactorial and perhaps related to increased sensitivity to general anesthetics or blunted central adrenergic response to pharmacologic-induced hemodynamic perturbations (eg, cardiovascular depressant effect of general anesthesia). Although not previously described, the latter 2 factors may result from compromised cardiovascular centers within the central nervous system in this patient population. Unfortunately, it was beyond the intended scope of the present study to ascertain interventions undertaken to treat these hypotensive events.

Thermoregulation—Hypothermia (defined as a core temperature < 35.5°C) topped the list (n = 441, 55.1%) of perioperative complications observed in our study, with an incidence exceeding one-half of our patients (Figure 1). The etiology is difficult to elucidate, as so many factors (eg, radiation, conduction, convection, and evaporation) come into play during general anesthesia and surgery.^{1,5,11} However, specific to this patient population, one must consider the poikilothermic role of abnormal thermoregulatory mechanisms in patients with a compromised central nervous system.⁵ Major in vivo consequences of mild hypothermia include increased surgical wound infection, extended duration of hospitalization, more profound surgical blood loss and allogeneic blood transfusion, morbid cardiac events including ventricular tachycardia, prolonged neuromuscular blockade, delayed emergence, shivering, and thermal discomfort.¹¹ In regard to thermoregulation, it deserves mention that care providers may receive diminished reimbursement for certain patient populations (eg, those undergoing colorectal surgery) leaving the operating room in a hypothermic condition, as this has been linked to increased surgical site infections.¹² Abstracting preoperative temperatures from the patient's medical records would have provided useful information in helping us elucidate whether preexisting hypothermia was—in part—responsible for our most common perioperative complication. As such, we see this as a limitation of our study.

Historically (eg, during the study interval of this project), hypothermia was treated using intravenous fluid and whole-body warming devices. More recently, our institution as a whole has become more aware and aggressive toward perioperative temperature management. Accordingly, in addition to the above-mentioned interventions, we now

routinely initiate forced-air whole-body warming in the preoperative holding area to mitigate heat loss during the early stages of general anesthesia.

Gastrointestinal—Gastroesophageal reflux disease is common in patients with cerebral palsy, and these individuals often present to the operating room for Nissen fundoplication.⁵ For example, in our study population, 221 patients (27.6%) had a preoperative diagnosis of gastroesophageal reflux disease. Accordingly, it would seem intuitively obvious cerebral palsy patients are at increased risk of perioperative aspiration of gastric contents.

However, our data were not supportive, as the frequency of aspiration was only 0.5%. Our observations may be explained by the fact that the vast majority of our patients were nil orally since midnight, optimized with antacid medications (eg, H₂ antagonists, proton pump inhibitors), and those known to have florid gastroesophageal reflux disease routinely received the Sellick maneuver¹³ (ie, pressure applied to the cricoid cartilage thereby occluding the underlying esophagus to prevent gastric contents from soiling the airway) during induction of general anesthesia.

Motor dysfunction and antispasmodic medications—There is evidence that the severity of cerebral palsy is related to gross motor function.¹⁴ However, characterization of the severity of gross motor function using a classification system is often difficult and beyond the intended scope of this investigation.¹⁴

Medically, one of the greatest challenges faced when caring for cerebral palsy patients is controlling spasticity and preventing contractures. Pharmacologically, this is often achieved using medications (oral or intrathecal) that modulate central or peripheral nervous system motor tone. Examples of centrally acting medications that increase inhibitory or decrease excitatory central nervous system neurotransmission include baclofen (γ -aminobutyric acid- β receptor agonist), benzodiazepines (γ -aminobutyric acid- α receptor agonist), vigabatrin (γ -aminobutyric acid transaminase [enzyme responsible for γ -aminobutyric acid catabolism] inhibitor), and tizanidine (central acting α_2 agonist).¹ Of concern to the anesthesia care team, all of these medications have the potential to cause dose-dependent drowsiness, sedation, ataxia, dizziness, and lethargy. Accordingly, intrathecal administration recently has been advocated in an attempt to mitigate or prevent these undesirable side effects. However, it deserves mention that intrathecal baclofen can cause the above-mentioned adverse reactions in addition to confusion and hypotonia.^{1,3,15}

Peripheral acting drugs include botulinum toxin (Bo-Tox), which is injected directly into the muscle to produce functional denervation by preventing presynaptic acetylcholine release.^{1,3} Alternatively, in extreme cases, dantrolene (which inhibits calcium reuptake into skeletal muscle sarcoplasmic reticulum) can be used to relax spastic muscles.¹ In either case, possible unwanted side effects include generalized or respiratory weakness and lethargy.¹

Other comorbid conditions—Depending on the nature of underlying brain lesion, approximately 30% of cerebral palsy patients may have coexisting epilepsy.^{3,5} There are anecdotal observations and case reports suggesting that general anesthesia in these individuals may increase in the frequency and/or duration of seizure activity, cause status epilepticus, alter pharmacokinetic and pharmacodynamic response (resulting from antiepileptic drugs) of anesthetic medications, and delay emergence (ie, difficulty awakening from anesthesia) following surgery. In regard to increased perioperative seizure activity, certain anesthetics are known to lower the seizure threshold. Medications implicated in this pathophysiologic response include inhaled volatile anesthetics (eg, enflurane, sevoflurane), local anesthetics (eg, lidocaine, bupivacaine), opioids (eg, fentanyl, alfentanil, sufentanil, meperidine), and some sedative hypnotic medications (eg, propofol,

etomidate, ketamine, methohexital). Despite these seizure-related issues, we¹⁶ previously reported no significant increase in adverse outcomes in epilepsy patients undergoing general anesthesia.¹⁶ In that study,¹⁶ we reported epileptiform activity in only 2% of all seizure patients. In contrast, in the present study we observed that the frequency of perioperative seizures was significantly greater in individuals with preexisting seizure disorder ($n = 341$) than individuals without (5.3% vs 0.2%, $P < .001$). In comparison with our previous report,¹⁶ cerebral palsy patients with coexisting epilepsy were more than twice (ie, 5.3% vs 2.0%) as likely to experience a perioperative seizure than noncerebral palsy epileptic patients undergoing surgery. Unfortunately, it is difficult to draw any conclusions about this disparity, as the sample size for perioperative seizures was too small to have meaningful statistical power.

American Society of Anesthesiologists physical status score and population age—

Others have reported increasing American Society of Anesthesiologists physical status score and pediatric patient populations correlate with increased incidence of perioperative complications.¹⁷ Data from the present study are mixed. For example, higher American Society of Anesthesiologists scores were associated with a proportionally greater percentage of perioperative complications. However, in regard to age, our youth were less likely than adults to experience an adverse perioperative event.

Perioperative Care Team-Related Implications—Taken together, it would seem intuitively obvious that cerebral palsy patients would be at increased risk for: delayed emergence, aspiration of gastric contents, difficult tracheal intubation, pneumonia, respiratory embarrassment (resulting from an exacerbation of the baseline extrinsic restrictive lung physiology associated with scoliosis or inability to clear copious secretions), latex allergies, positioning-related difficulties (related to skeletal muscle contractures and scoliosis), increased seizure frequency, hemodynamic instability, hypothermia, or unpredictable sensitivity/resistance to muscle relaxants and general anesthetics (eg, lower minimal alveolar concentration, increased narcotic sensitivity) associated with their baseline disease process or the medications used to treat related comorbidities (see above). After factoring out hypotension and hypothermia, delayed emergence topped the list of complications ($n = 45$, 5.6%; Figure 1). The etiology was likely related to baseline increased sensitivity to general anesthetics in patients with a compromised central nervous system, dose-dependent drowsiness associated with antispasmodic medications, and a high frequency of perioperative hypothermia. It deserves mention that a potential limitation of this observation is the subjective nature of defining delayed emergence as a recovery time exceeding one hour. In our clinical practice, these individuals are expectantly watched rather than treated with medications.

There are anecdotal observations and case reports suggesting the severity of preoperative cerebral palsy comorbidity correlates directly with postoperative complications. Unfortunately, the most comprehensive analysis of this comes from a retrospective study with a very small sample size ($n = 107$) in a limited surgical population (patients undergoing spine surgery).¹⁰ However, more convincing evidence is lacking in our literature as to whether these individuals are at increased risk for perioperative morbidity and mortality. Previously published research quote anesthetic mortality ranging from 0.05 to 10 per 10000 administered anesthetics.¹⁸ Our study indicates the mortality rate for cerebral palsy patients undergoing elective or emergent surgery is well-within the acceptable range at 0.1%.

Aside from the study limitations cited above, another consideration was that we did not evaluate the impact of perioperative complications on hospital length of stay. Making this determination would have been useful in helping the care team better anticipate utilization of hospital and staffing resources.

Summary

In this retrospective analysis of pediatric and adult cerebral palsy patients undergoing surgery, the risk of perioperative morbidity and mortality was 63% and 0.1%, respectively. The majority of the individuals in this investigation were pediatric patients. As such, we observed a greater number of complications in pediatric patients when compared with adults. However, as a percentage, adults were at greater risk of a perioperative complication. Other factors associated with increased risk for experiencing an adverse perioperative event included individuals with an American Society of Anesthesiologists physical status score exceeding 2, a history of seizures, and upper airway hypotonia as well as those undergoing general surgery procedures. Patients meeting these criteria were at increased risk for perioperative hypothermia, hypotension, delayed emergence from general anesthesia, seizures, and airway-related morbidity.

The current findings may be useful to counsel and guide patients with cerebral palsy, their caregivers, and their guardians regarding the risk of general anesthesia.

Acknowledgments

We express deep gratitude to Shonie Buenvenida and the Anesthesia Clinical Research Unit for providing us access to the Mayo database.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

1. Wongprasartsuk P, Stevens J. Cerebral palsy and anaesthesia. *Paediatr Anaesth*. 2002; 12:296–303. [PubMed: 11982834]
2. Mutch L, Alberman E, Hagberg B, Kodama K, Perat MV. Cerebral palsy epidemiology: where are we now and where are we going? *Dev Med Child Neurol*. 1992; 34:547–551. [PubMed: 1612216]
3. Maranhao MV. Anesthesia and cerebral palsy. *Rev Bras Anestesiol*. 2005; 55:680–702. [PubMed: 19468543]
4. Murphy N, Such-Neibar T. Cerebral palsy diagnosis and management: the state of the art. *Curr Probl Pediatr Adolesc Health Care*. 2003; 33:146–169. [PubMed: 12738938]
5. Theroux MC, Akins RE. Surgery and anesthesia for children who have cerebral palsy. *Anesthesiol Clin North America*. 2005; 23:733–743. ix. [PubMed: 16310661]
6. Davies J. Anesthesia malpractice claims for newborn brain injury in the 1990s. *ASA Newsletter*. 2006; 70:14–16.
7. Jacobsson B, Hagberg G. Antenatal risk factors for cerebral palsy. *Best Pract Res Clin Obstet Gynaecol*. 2004; 18:425–436. [PubMed: 15183137]
8. Nolan J, Chalkiadis GA, Low J, Olesch CA, Brown TC. Anaesthesia and pain management in cerebral palsy. *Anaesthesia*. 2000; 55:32–41. [PubMed: 10594431]
9. Steiner M, Hodes MZ, Shreve M, Sundberg S, Edson JR. Postoperative stroke in a child with cerebral palsy heterozygous for factor V Leiden. *J Pediatr Hematol Oncol*. 2000; 22:262–264. [PubMed: 10864060]
10. Lipton GE, Miller F, Dabney KW, Altiock H, Bachrach SJ. Factors predicting postoperative complications following spinal fusions in children with cerebral palsy. *J Spinal Disord*. 1999; 12:197–205. [PubMed: 10382772]
11. Sessler, D. Temperature regulation and monitoring. In: Miller, RD.; Eriksson, LI.; Fleisher, LA.; Wiener-Kronish, JP.; Young, WL., editors. *Miller's Anesthesia*. 7th ed.. Philadelphia: Churchill Livingstone; 2010. p. 1533-1556.
12. [Accessed April 4, 2011] Institute for Healthcare Improvement. <http://www.ihl.org/IHI/Topics/PatientSafety/SurgicalSiteInfections/Changes/SSI+Maintain+Normothermia.htm>.

13. Sellick BA. Cricoid pressure to control regurgitation of stomach contents during induction of anaesthesia. *Lancet*. 1961; 2:404–406. [PubMed: 13749923]
14. Palisano RJ, Hanna SE, Rosenbaum PL, et al. Validation of a model of gross motor function for children with cerebral palsy. *Phys Ther*. 2000; 80:974–985. [PubMed: 11002433]
15. Gomar C, Carrero EJ. Delayed arousal after general anesthesia associated with baclofen. *Anesthesiology*. 1994; 81:1306–1307. [PubMed: 7978496]
16. Benish SM, Cascino GD, Warner ME, Worrell GA, Wass CT. Effect of general anesthesia in patients with epilepsy: a population-based study. *Epilepsy Behav*. 2010; 17:87–89. [PubMed: 19910260]
17. Fleisher, L. Risk of anesthesia. In: Miller, R.; Eriksson, L.; Fleisher, L.; Wiener-Krinish, J.; Young, W., editors. *Miller's Anesthesia*. 7th ed.. Philadelphia: Churchill Livingstone; 2010. p. 969-999.
18. Arbous MS, Meursing AE, van Kleef JW, et al. Impact of anesthesia management characteristics on severe morbidity and mortality. *Anesthesiology*. 2005; 102:257–268. quiz 491–492. [PubMed: 15681938]

Figure 1.
Percentage of cerebral palsy patients experiencing perioperative complications.

Table 1Univariate Analysis of Characteristics Potentially Associated With Complications Other Than Hypothermia and Hypertension^a

Characteristic	Total n	n	(%)	Odds Ratio	95% Confidence Interval	P
Age						.05
Pediatric	517	59	11.4	1.0		
Adult	283	46	16.2	1.51	0.99–2.28	
Sex						.29
Male	457	65	14.2	1.0		
Female	343	40	11.7	0.80	0.52–1.21	
Type of procedure						.02
Orthopedic	260	31	11.9	1.0		
Radiology	130	10	7.7	0.62	0.29–1.30	
Ear, nose, and throat	108	11	10.2	0.84	0.40–1.73	
General surgery	100	23	23.0	2.21	1.21–4.01	
Neurologic	98	11	11.2	0.93	0.45–1.94	
Gastrointestinal	50	9	18.0	1.62	0.72–3.66	
Other	54	10	18.5	1.68	0.77–3.67	
Emergency						.81
No	787	103	13.1	1.0		
Yes	13	2	15.4	1.21	0.26–5.52	
ASA physical status						<.001
2	415	38	9.2	1.0		
3	376	66	17.6	2.11	1.38–3.24	
Blindness						.38
No	727	93	12.8	1.0		
Yes	73	12	16.4	1.34	0.70–2.58	
Drooling						.76
No	733	97	13.2	1.0		
Yes	67	8	11.9	0.89	0.41–1.92	
Feeding tube						.003
No	687	80	11.6	1.0		
Yes	113	25	22.1	2.16	1.30–3.56	

Characteristic	Total n	n	(%)	Odds Ratio	95% Confidence Interval	P
Gastrointestinal reflux						.01
No	579	65	11.2	1.0		
Yes	221	40	18.1	1.75	1.14–2.68	
Latex allergy						.53
No	777	103	13.3	1.0		
Yes	23	2	8.7	0.62	0.14–2.70	
Malnourished						.005
No	713	85	11.9	1.0		
Yes	87	20	23.0	2.20	1.28–3.82	
Mental retardation						.24
No	339	39	11.5	1.0		
Yes	461	66	14.3	1.28	0.84–1.96	
History of pneumonia						.001
No	703	82	11.7	1.0		
Yes	97	23	23.7	2.35	1.40–3.96	
Reactive airway disease						.012
No	695	83	11.9	1.0		
Yes	105	22	21.0	1.95	1.16–3.30	
History of aspiration						.002
No	708	83	11.7	1.0	1.39–4.02	
Yes	92	22	23.9	2.37		
Scoliosis						.02
No	714	87	12.2	1.0		
Yes	86	18	20.9	1.91	1.08–3.36	
History of seizures						.01
No	459	48	10.5	1.0		
Yes	341	57	16.7	1.72	1.14–2.60	
Tracheostomy						.36
No	780	101	13.0	1.0		
Yes	20	4	20.0	1.68	0.55–5.13	
Upper airway hypotonia						<.001

Characteristic	Total n	n	(%)	Odds Ratio	95% Confidence Interval	P
No	758	90	11.9	1.0		
Yes	42	15	35.7	4.12	2.11–8.05	

Abbreviation: ASA, American Society of Anesthesiologists.

^aFor these analyses each characteristic was assessed separately using logistic regression. In all cases, the dependent variable was a binary indicator representing the occurrence of any of the following perioperative complications: delayed emergence, seizure, airway obstruction, pneumonia, stridor, bronchospasm, neuromyopathy, reintubation, aspiration and laryngospasm. Findings from these logistic regression analyses are summarized using the odds ratio and corresponding 95% confidence interval.

Table 2

Multivariate Analysis Assessing Characteristics Associated With Complications Other Than Hypothermia and Hypertension^a

Characteristic	Odds Ratio	95% Confidence Interval	P
Age			.04
Pediatric	1.0		
Adult	1.59	1.01–2.50	
Type of procedure			.02
Orthopedic	1.0		
Radiology	0.40	0.18–0.90	
Ear, nose and throat	0.56	0.26–1.21	
General surgery	1.71	0.91–3.20	
Neurologic	0.65	0.30–1.40	
Gastrointestinal	1.01	0.43–2.40	
Other	1.05	0.46–2.41	
ASA physical status			.03
2	1.0		
3	1.66	1.05–2.62	
History of seizures			.02
No	1.0		
Yes	1.70	1.10–2.66	
Upper airway hypotonia			<.001
No	1.0		
Yes	4.54	2.18–9.48	

Abbreviation: ASA, American Society of Anesthesiologists.

^aA multiple logistic regression analysis with backward elimination of nonsignificant variables was performed with all characteristics presented in Table 1 included as explanatory variables in the first step. Findings from the final model, after backward elimination of nonsignificant variables, are presented.