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Anesthetic Regimens for Intraoperative Bulbocavernosus Reflex Monitoring in Pediatric Tethered Cord Surgery, Experiences from the University Hospital

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Background: Anesthetic management for intraoperative bulbocavernosus reflex (BCR) monitoring is challenging, particularly in pediatric patients.

Objective: The aim of this study was to demonstrate anesthetic regimens for successful intraoperative BCR monitoring in pediatric patients.

Methods: This retrospective descriptive study was done in pediatric patients who underwent untethered cord surgery with intraoperative BCR monitoring. The data collections were preoperative urinary and anal sphincter function, anesthetic technique, monitorable of BCR, significant change of BCR signal, duration of surgery and anesthesia. The outcomes collected were from postoperative urinary and anal sphincter dysfunction, length of ICU and hospital stay.

Results: Seventeen patients obtained intraoperative BCR monitoring during untethered cord surgery for a 3-years period. Intraoperative BCR signal could be recorded in all patients during anesthetic maintenance with total intravenous anesthesia (TIVA) consisting of propofol and fentanyl infusion without muscle relaxant. Mean doses of propofol and fentanyl during BCR monitoring were 170.77±29.84 mcg/kg/min and 1.87±0.91 mcg/kg/hr, respectively. After finishing BCR monitoring, anesthesia was switched to inhalation anesthetics in 16 patients (94.12%). All patients were extubated in the operating room without postoperative ICU admission. Significant BCR signal changes were recorded in three patients. One of these patients had postoperative urinary dysfunction. All of them were discharged without complications.

Conclusions: Intraoperative BCR was monitorable during anesthetic maintenance with TIVA using propofol and fentanyl without muscle relaxant in conjunction with maintenance of hemodynamic stability. This anesthetic regimen may contribute to a good neurological outcome as BCR signal was preserved and facilitate extubation.

Keywords: anesthesia, intraoperative bulbocavernosus reflex (BCR), pediatric, tethered cord surgery, urinary dysfunction

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Spinal dysraphism is congenital neural tube defects with incidence about 2.73 to 3.80 per 10,000 live births in the United State.[1] This anomaly may cause neurological dysfunction from retraction of spinal cord in vertebral canal, namely tethered cord syndrome. The early days of surgery for spinal dysraphism is beneficial due to progressive and irreversible neurologic dysfunction, especially in pediatric patients.[2] However, the surgery can lead to neural structure injury and new neurological deficit. The incidence of neurological

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complications after untethering surgery was reported about 11% in children[3] compared to 3.5% in adults.[4]

Intraoperative neurophysiologic monitoring (IONM) has gained useful to detect and prevent neurological damage during surgery. Intraoperative somatosensory evoked potential (SSEP), motor evoked potential (MEP), electromyography (EMG) and bulbocavernosus reflex (BCR) have been used as valuable continuous monitoring in sacral surgery since 1997.[5] BCR is a sensorimotor reflex arc reflected the functional integrity of S2-4 sacral segments that enables urinary and bowel function.[5-11] The afferent pathway is composed of the sensory branch of pudendal nerve (dorsal penile or clitoral nerve), sacral plexus, and sacral roots of S2-4, and the efferent pathway is consisted of somatic and parasympathetic fibers. The Onuf's nucleus located in the ventral horn of the spinal cord, sacral roots of S2-4, pudendal nerve, the external anal and urethral sphincter are the components of the somatic motor pathway. The efferent parasympathetic motor pathway is composed of sacral roots of S2-4, pelvic nerve, and bladder.[12] There are many advantages of the BCR monitoring over other IONM including both stimulation and recording are performed outside the surgical field, therefore the monitor does not interrupt the surgery.[5,13,14] Moreover, it is no time-consuming test because BCR monitoring is obtained after only one train of stimulation, as the technical issue of the monitor.[14] The BCR recording has 2 components; the early response (R1) with the oligosynaptic pathway and the late response (R2) with the polysynaptic pathway.[6,15] Both responses were mediated by synaptic relays within the conus medullaris after dorsal penile/clitoral nerve stimulation in a laboratory. But the early response is more easily elicited during general anesthesia.[6] Because BCR is an oligosynaptic reflex, the signal may be abolished by general anesthesia, especially inhalation and muscle relaxant.[7,8,15] Anesthetic management for intraoperative BCR monitoring is still challenging, particularly in pediatric patients. A lot of studies demonstrated anesthetic regimens for MEP and SSEP, but the anesthetic regimens for BCR monitoring are reported less. The aim of this study was to illustrate the anesthetic regimens for successful intraoperative BCR monitoring in pediatric patients in a university hospital. We also measured postoperative outcomes such as urinary and anal sphincter dysfunction after untethering surgery with intraoperative BCR monitoring.

Methods

This retrospective descriptive study was approved by the Chulalongkorn University Institutional Review Board. (IRB No.785/63) We reviewed the pediatric patients' charts (0 to 15 years old) who underwent untethered cord surgery with intraoperative BCR monitoring in a 3 years period between November 2017 and October 2020 at King Chulalongkorn Memorial Hospital. Incomplete patients' medical records were excluded. The data collected were demographic data, pathological diagnoses, ASA physical status, preoperative urinary function and anal sphincter status, types of IONM, anesthetic techniques including inhalation anesthetic, total intravenous anesthesia (TIVA), muscle relaxant and opioid use, intraoperative BCR monitorability, numbers of patients with a significant change of BCR signal, duration of surgery and anesthesia, intraoperative hypotensive episode, body temperature, and blood transfusion. Hypotension was defined as the decrease in systolic blood pressure of more than 20% from baseline or vasopressor/inotropic agents required. Numbers of patients with postoperative urinary and anal sphincter dysfunction, length of ICU stay and hospital stay were collected as the outcome. In our institute, IONM was performed by neuroanesthesiologists who provided anesthesia. Intraoperative BCR monitoring was conducted using the NIM-Eclipse NS system (Medtronic Xomed Inc). Sterile needle electrodes were used to stimulate the dorsal penile or clitoral nerve. The cathode was on the proximal penis or clitoris and the anode was on the distal penis or labia majora. The recording was made from the anal sphincter using subdermal needle electrodes. (Figure 1) These needles were fixed with adhesive tape to the skin after cleaning with alcohol. The stimulation settings were a single train of four stimulation pulsed with duration of 0.5 ms, an interstimulus interval of 2 ms. The stimulus intensity was started with 5 mA and increased to a maximum of 40 mA for generating a recordable BCR waveform. A summation or averaging was not performed. The filter was set at 30 to 500 Hz. The evaluation of BCR response was detected the peak-to-peak amplitude between the maximum negative and positive peaks in the first response (R1), onset latency was about 30 to 35 ms.[6]

The BCR response was defined as an amplitude at least 3 μV for distinguishing from baseline noise.[7] The alert criteria of BCR response was a persistent reduction of amplitude greater than 50% from baseline. The patients would be checked and managed according to the IONM signal change protocol of our institute. The significant changes of BCR signal were recorded in both the operative reports and the anesthetic records.

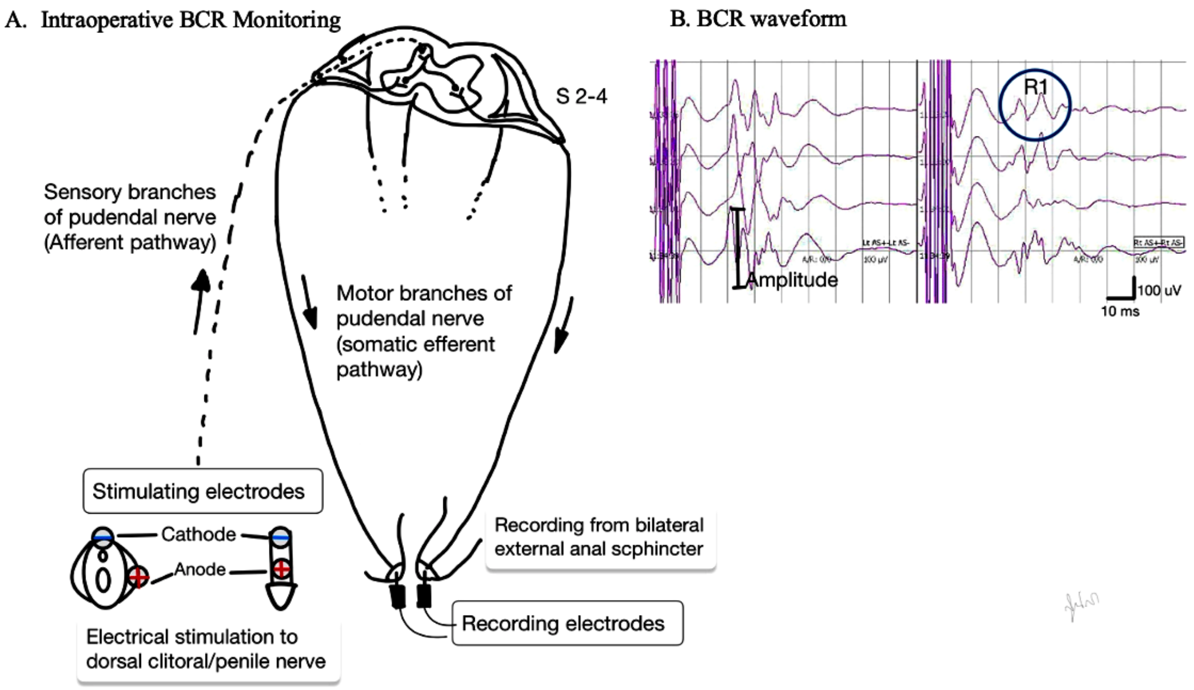

Figure 1 A. Intraoperative bulbocavernosus reflex (BCR) monitoring. B. BCR waveform recorded form our patient. Amplitude is positive peak to negative peak. We observed early signal (R1) on latency about 30-40 ms. Abbreviation: BCR, bulbocavernosus reflex; R, response; S, sacrum.

Statistical analysis

The anesthetic techniques including the use of inhalation, muscle relaxant, or intravenous anesthetic agents were presented as numbers and percentages. Demographic variables included the mean doses of propofol and fentanyl that were continuous and normally distributed were expressed as means with standard deviations whilst categorical variables such as numbers of patients with postoperative urinary and anal sphincter dysfunction were expressed as numbers and percentages. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for predicting postoperative urinary dysfunction were also calculated.

Results

Forty-six children underwent untethered cord surgery in the period between November 2017 and October 2020. We excluded 29 children who were not monitored with IONM in 21 patients and were monitored with IONM except BCR in 8 patients. There were 17 patients who obtained with intraoperative BCR monitoring. The demographic and perioperative data were shown in Table 1. The majority of patients were female (70.59%) with age under 2 years old (76.47%). The diagnoses were spinal cord lipoma in 12 patients, lipomyelomeningocele in 4 patients, and syringomyelia in one patient. There was only one patient (5.88%) who had preoperative urinary dysfunction with a record of recurrent urinary tract infection. Preoperative decreased anal sphincter tone was found in three children (17.65%).

Table 1 Demographic and perioperative data

Demographic data	Number of patients (n=17)
Age (months)	54.53 (6-322)
- 0-12 months	7 (41.18%)
- 13-24 months	6 (35.29%)
- > 24 months	4 (23.53%)
Body weight (kg)	12.56 (9.68)
Sex	
- Female	12 (70.59%)
- Male	5 (29.41%)
ASA Physical status	
- ASA 1	6 (35.29%)
- ASA 2	11 (64.71%)
- ASA 3-4	0 (0%)
Diagnoses	
- Spinal cord lipoma	12 (70.59%)
- Lipomyelomeningocele	4 (23.53%)
- Syringomyelia	1 (5.88%)
Preoperative urinary dysfunction	1 (5.88%)
Preoperative loose/decrease tone of anal sphincter	3 (17.65%)
Duration of operation (min)	338.59 (132-525)
Duration of anesthesia (min)	461.59 (207-717)
Intraoperative hypotension	0 (0%)
Intraoperative body temperature (°C)	36.06 (34.2-36.7)
Intraoperative blood transfusion	11 (64.71%)
Estimated blood loss (% of TBV)	11.44 (2.73-20.57)
Intraoperative BCR monitorable	17 (100%)
Intraoperative BCR signal changed	3 (17.65%)
Length of ICU stays (days)	0
Length of hospital stays (days)	7.59 (5-14)

Abbreviation: ASA, American Society of Anesthesiologists; BCR, bulbocavernosus reflex; ICU, intensive care unit; TBV, total blood volume. Values are reported as mean±SD, mean (range) or number (percentage) of patients.

The anesthesia was provided with the ASA standard monitoring. Anesthesia was induced with either sevoflurane and nitrous oxide or thiopental or propofol. (Table 2) Eight children (47.06%) were intubated without muscle relaxant while the others were intubated with succinylcholine (23.53%) or atracurium (29.41%). Soft bite block made from rolled gauze was typically placed in standard practice to avoid airway injury during MEP stimulation. Anesthesia was maintained with inhalation anesthetics, most were sevoflurane, during foley catheterization, intravenous catheter insertion and IONM needle electrodes placement. Muscle relaxant was not administered after intubation. After turning the patient to a prone position, the anesthetic technique was switched to TIVA consisting of propofol and fentanyl intravenous infusion. Baseline intraoperative BCR signal was obtained before incision when muscle relaxant was completely worn off. Mean doses of propofol and fentanyl during intraoperative BCR monitoring were 170.77±29.84 mcg/kg/min and 1.87±0.91 mcg/kg/hr, respectively. (Figure 2) Nitrous oxide was not used during intraoperative BCR monitoring. The Dose of anesthetic agents were adjusted according to patients' movement and cardiovascular response. Bispectral index (BIS) monitoring was used to monitor depth of anesthesia in an 11 years old male patient. BIS values were kept in the range of 20-44 with the mean dose of propofol of 122.24 mcg/kg/min and fentanyl of 1.17 mcg/kg/hr. A Bolus of intravenous anesthetics was avoided during monitoring to avoid signal interruption. After neurosurgeons finished their risky untethering operation and neuroanesthesiologist was asked to perform the final BCR test, propofol and fentanyl were discontinued in 16 patients (94.12%) and switched to sevoflurane until the end of the operation. Nitrous oxide as well as muscle relaxant were used in 4 of 17 patients (23.53%). Extubation was done without delayed emergence in all patients. None of them required postoperative ICU admission.

Table 2 Anesthetic techniques

Anesthetic technique	Number of patients (n=17)
Before BCR monitoring:	
Induction	
- sevoflurane	4 (23.53%)
- thiopental	3 (17.65%)
- propofol	10 (58.82%)
Intubation	
- no muscle relaxant	8 (47.06%)
- succinylcholine	4 (23.53%)
- atracurium	5 (29.41%)
Inhalation used	17 (100%)
- sevoflurane	16 (94.12%)
- desflurane	1 (5.88%)
During BCR monitoring:	
TIVA with propofol and fentanyl	17 (100%)
N_2O used	0 (0%)
Propofol dose (mcg/kg/min)	170.77 (100-270.5)
Fentanyl (mcg/kg/h)	1.87 (0.25-3.94)
After BCR monitoring:	
Inhalation used	16 (94.12%)
- sevoflurane	14 (87.5%)
- desflurane	2 (12.5%)
N_2O used	4 (23.53%)
Muscle relaxant used	4 (23.53%)
Extubation after finished operation in the OR	17 (100%)

Abbreviation: BCR, bulbocavernosus reflex; N_2O, nitrous oxide; TIVA, total intravenous anesthesia.

Values are reported as mean (range) or number (percentage) of patients.

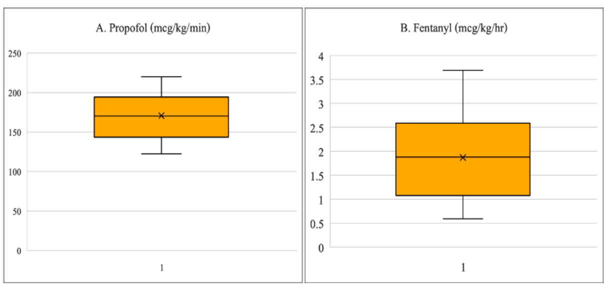

Figure 2 Box plots of the mean dose of propofol (A.) was 170.77 (±29.84) mcg/kg/min and the mean dose of fentanyl (B.) was 1.87 (±0.91) mcg/kg/h during intraoperative BCR monitoring. Abbreviation: BCR, bulbocavernosus reflex

Intraoperative BCR signal was successful obtained in all patients. The amplitude of the waveform permanently decreased more than 50% in three patients and did not recover until the end of the operation. Both hypotensive episode and hypothermia were not found. Mean body temperature was 36.06±0.61 °C. Red blood cell was transfused to correct anemia in 11 patients (64.71%). One patient with preoperative urinary dysfunction who developed significant intraoperative BCR signal deterioration continued to have significant residual urine volume in the postoperative period. Postoperative anal sphincter function was assessed from the history of fecal incontinence because the anal sphincter tone was not evaluated by the neurosurgeon. Although the BCR signal was significantly dropped during surgery, all 3 patients had no postoperative anal sphincter dysfunction. The Mean length of hospital stays was 7.59 (5-14) days. All patients were discharged home without complications of surgery and intraoperative BCR monitoring. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for predicting postoperative urinary dysfunction were shown in Table 3.

Table 3 The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the study. The alert criteria of BCR response was reduction of amplitude greater than 50% from baseline.

Greater 50% amplitude reduction in BCR amplitude	Postoperative urinary dysfunction		
	yes	no	
Yes	1	2	Positive predictive value (PPV) 33.33%
No	0	14	Negative predictive value (NPV) 100%
	Sensitivity 100%	Specificity 87.5%	

Discussion

Our study demonstrated the anesthetic regimens for successful intraoperative BCR monitoring in pediatric patients who underwent untethered cord surgery. After induction with inhalation or intravenous anesthetics and intubation with or without muscle relaxant, intraoperative BCR signals were successfully recorded in all patients under TIVA with propofol and fentanyl infusion. Anesthesia was changed to inhalation anesthetics after the risky untethering period to facilitate emergence and all patients in this study could be extubated in the operating room and returned to the regular ward.

We found the BCR waveform amplitude significantly decreased in 3 patients. One of these patients presented with preoperative urinary dysfunction and continued to have postoperative residual urine in bladder while the other 2 patients did not have postoperative urination and defecation problems. The BCR signal could be recorded in 3 patients with preoperative loose anal sphincter. All patients had good neurological outcomes after surgery.

The Success rate of monitoring was demonstrated less in female than male with related to partly technical and partly physiological.[10] Moreover, intraoperative BCR signal may not be obtained due to inadequate technical stimulation, complicated lesion with sacral dysfunction or preoperative neurological deficit.[7] Immature peripheral and central nervous system in very young patients can also cause difficulty in obtaining MEP and BCR signal.[13,16] However, our study showed that intraoperative BCR was effectively monitored in both the early aged and female patients.

TIVA with propofol and short-acting opioid were recommended anesthetics for MEP and BCR monitoring.[8,10,13,17-19] Inhalation anesthetics and muscle relaxants should be avoided because BCR is an oligosynaptic reflex that will be easily suppressed by inhalation anesthetics. However, some studies described a 59-100% intraoperative BCR monitorability rate with the various anesthetic regimens.[5,7,8,10,11] Deletis et al. showed that the BCR signal was suppressed by administration of either 1.25% isoflurane or 60% nitrous oxide for 15 minutes and this effect still lasted for 30 minutes after isoflurane was discontinued.[5] Although many studies recommended using TIVA technique during intraoperative BCR monitoring,[5,6,7,8,11,14] inhalation with or without nitrous oxide could be used in a few studies.[5,7,11,14] Three studies illustrated successful BCR monitoring while using 0.5-2.0 % sevoflurane anesthesia with maintaining the BIS values of 40-60.[7,11,14] Hoving et al. reported the change of anesthetic regimen from inhalation anesthesia to TIVA when it was difficult to get the good BCR signal would result in successfully BCR recording.[11] Some studies showed that 0.3-0.5 MAC of either sevoflurane or desflurane, with or without nitrous oxide did not disturb MEP signal responding.[20-23] However, they also reported some problems such as more variable response, greater intensity of stimulation, higher rate of unnecessary alert, created ambivalence in interpretation, and delays surgery.[22] Therefore inhalation anesthetics should be used with caution, and promptly changed to TIVA technique when the signals were not determined. The inhalation anesthetics with less tissue solubility, sevoflurane and desflurane, was preferred according to a rapid change of concentration, hence, sevoflurane was appropriate to use as inhalation induction for BCR monitoring.[24] Nitrous oxide had a weak anesthetic effect but it causes a profound depressant effect on the IONM signal.[25] Therefore, a low concentration of inhalation anesthetics alone was preferred over an equivalent dose of inhalation anesthetics with nitrous oxide.[24] We showed successfully intraoperative BCR recording with sevoflurane and nitrous oxide induction and change to TIVA anesthesia after positioning. The doses of both propofol and fentanyl in this study were higher than the previous studies owing to patients' response. However, hemodynamic variables such as blood pressure and body temperature were all maintained within the normal limit. The literature reported the dose range of propofol for maintenance of anesthesia during IONM including BCR monitoring were 33 to 250 mcg/kg/min.[7,8,11,14,17-19,22,23] The high doses of propofol, 250-300 mcg/kg/min, resulted in MEP response suppression,[22,24] while MEP recording was compatible with propofol doses lower than 175 mcg/kg/min.[26] However, the usual doses range of propofol with various types of opioids were 100-150 mcg/kg/min. Opioids with excellent analgesia have a very mild effect on IONM responses.[24] Fentanyl 1 mcg/kg/hr[8,18], remifentanil 0.1-1 mcg/kg/min[7,14,22], sufentanil 0.2-0.6 mcg/kg/min[17,19] were reported in various studies. To the best of our knowledge, this is the first study that demonstrates the mean dose of propofol and fentanyl during intraoperative BCR monitoring in children. Although the mean dose of propofol (170.77±29.84 mcg/kg/min) is rather high to maintain patients' immobility, intraoperative BCR signal was still successfully recorded in all patients. Several studies demonstrated that younger patients required a higher dose of propofol for adequate anesthesia.[27] The concerns of high dose propofol infusion were propofol infusion syndrome and hypotension. Alternative intravenous anesthetic agents such as benzodiazepines, ketamine, dexmedetomidine, and etomidate might be used during MEP and SSEP monitoring[24] but further studies for BCR monitoring are needed. A Combination of low doses of inhalation anesthetics and propofol were proposed for propofol dose reduction. Sloan et al. showed that 3% desflurane with propofol and/or opioids were able to reduce propofol doses from 115 to 45 mcg/kg/min compared with TIVA during IONM.[28] Lieberman et al. demonstrated that MEP monitoring in children was compatible with 0.75-1% isoflurane and propofol 50-75 mg/kg/min.[16] Depth of anesthesia monitoring with BIS might be beneficial for anesthetic dose adjustment. However, the accuracy of BIS monitoring was questionable in children especially infants.[29,30] In the present study, one patient who was monitored with BIS was likely to receive a lower dose of propofol. Even the use of high doses of propofol in this study, we did not experience an episode of intraoperative hypotension requiring vasopressor drugs and all patients were able to extubate immediately in the operating room.

Both MEP and BCR response were derived from muscle action potential, therefore muscle relaxant should be avoided.[5-7,10,13,17] A Short-acting muscle relaxant should be used to facilitate orotracheal intubation so that its effect would be weaned off during the monitoring period. Rocuronium, atracurium, or vecuronium were all documented in the literatures.[7,14,17,21,23] Nevertheless, successful MEP monitoring during partial neuromuscular block by maintaining train-of-four of 2 or 3 twitches was reported.[23,31] The benefit of maintaining partial neuromuscular blockade is to avoid high doses of propofol which might cause hypotension and result in vasopressors requirement.[31] However, the partial neuromuscular blockade can result in inadequate MEP and BCR response. Therefore, we suggested providing TIVA without muscle relaxant during BCR recording to avoid questionable interpretation of the signals. After the risky operative period, anesthesia can be changed to inhalation anesthetics with muscle relaxant in order to avoid a high dose of propofol and to facilitate emergence.

There are many limitations of the BCR monitoring. False positive can occur during spinal manipulation which causes fluctuation in BCR amplitude without clinically significant. "Anesthetic fade" in which MEP amplitude gradually declined over anesthetic time can also cause false positive. Prolong exposure to anesthetic agents (5-6 hours) caused a higher stimulation threshold to elicit MEP response. Mechanisms of this anesthetic fade were multiple confounding factors including accumulated plasma level of propofol in the brain progressively inhibited anterior horn cells.[32] Careful interpretation could avoid these false positive finding. In this present study, the mean duration of anesthesia was 7.7 hours. This prolonged exposure to anesthesia might affect BCR signal amplitude from this phenomenon without causing the postoperative neurological deficit. False negative can also occur as the injured suprasegmental pathway controlling sphincter activity was not detected by the BCR monitoring. The SSEP or MEP monitoring have been widely implemented to detect this suprasegmental pathway. Nowadays, an alert criterion of intraoperative BCR had not reached a consensus. Both persisted suppression of amplitude greater than 50% from baseline or loss of signal were reported as an alert criterion.[7,9] Morota et al. recommended the cutoff value of 75% amplitude reduction with the PPV of 53% and NPV of 98.5% for predicting postoperative urinary complications.[15] Shinjo et al. showed that an alert criterion of greater 50% reduction in BCR amplitude had a PPV of 37.5% and NPV of 100%.[7] Our study had the same results, we used the cutoff value of greater than 50% BCR amplitude reduction and found the PPV of 33.3% and NPV of 100% to predict postoperative urinary dysfunction.

Sudden repeatable disappearance of BCR responses should be alarmed if physiologic and anesthetic conditions were previously stable, especially during risky surgical manipulation. Decreased waveform complexity may help to early warn before signals are lost.[6] When the BCR amplitude suddenly decrease greater than 50%, anesthesiologists should follow the IONM alert protocol. We should notice the neurosurgeon first. Then evaluate and correct all physiologic conditions affecting IONM such as hypotension, hypothermia and anemia. A Bolus of sedative drugs, muscle relaxants, and inhalation anesthetics also causes suppression of BCR amplitude. If decreased BCR amplitude persisted after correcting all physiologic and anesthetic factors, a warm saline irrigation might help recovery of decreased signal.[9] After recovery of the BCR signal, the operation should be continued with caution. Even intraoperative BCR was preserved, postoperative urinary complications might have occurred.

Complications related to IONM should be concerned as bleeding/burning at the site of electrodes and tongue/teeth injury.[19,33] Transcranial stimulation in MEP monitoring may directly activate temporalis muscle and clench the jaw. In conjunction with the avoidance of muscle relaxants, these can cause airway injury.[33] Bite block placement is a standard practice during MEP monitoring to avoid these airway injuries. Our study found that BCR was successfully monitored in all patients without any complications. Although these complications were less reported, anesthesiologists should take into consideration and inform the patients about these risks.

There were some limitations in the present study. Firstly, the data was analyzed from the medical records, retrospectively. Secondly, the number of cases was quite small so the results of data should be interpreted carefully. Thirdly, our study did not have data of emergence time from the end of operation to extubation. Thus, we were not able to summarize that delayed emergence was caused by the use of TIVA technique. Fourthly, postoperative anal sphincter function was only evaluated by a history of fecal incontinence from the parents without direct evaluation of sphincter tone. Therefore, it was difficult to interpret the predictability on the outcome of bowel function. Finally, this study did not have ล data of long-term follow up outcome after surgery to estimate the values of this modality.

Conclusion

Among pediatric patients undergoing untethered cord surgery, the anesthetic regimen for successful intraoperative BCR monitoring consisted of sevoflurane induction followed by TIVA using propofol and fentanyl without muscle relaxant for anesthetic maintenance in conjunction with the maintenance of hemodynamic stability. These anesthetic techniques resulted in monitorable BCR signal that may contribute to a good neurological outcome. However, further large, well-designed randomized controlled trial, cohort studies are needed to validate our conclusions.

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