Pediatric Corrective Spine Surgery: "The Concerns and Essentials of Anaesthetic Management"

Ridhima Sharma[1], Anju Gupta[1,*], Ripon Choudhury[2], Nishkarsh Gupta[3] and Rohan Magoon[4]

[1]*VMMC & Safdarjung Hospital, New Delhi;* [2]*Max Hospital, Patparganj, Delhi;* [3]*IRCH, AIIMS, New Delhi;*

[4]*AIIMS, New Delhi*

Abstract: The perioperative management of children undergoing surgical correction of spinal deformities is challenging, even in the hands of an experienced anesthesiologist. A comprehensive plan is imperative keeping in mind that the surgery is extensive, the patients have other significant organ involvement and the need for neurophysiological monitoring to assess cord function and prevent neurological deficit. Meticulous prone positioning and the application of various blood- sparing techniques are an integral part of the intraoperative management. The pre-operative status and the intra-operative events could help in predicting the need for post-operative ventilatory support. The present article aims to elucidate the importance of a streamlined evaluation, monitoring, management strategy and stratification of these patients for a favorable outcome.

Keywords: Paediatric, Spine surgery, Evoked potentials.

INTRODUCTION

Spine surgery is contemplated in the paediatrics for varied pathologies, including congenital or idiopathic defects, primary or metastatic malignancy, infected abscesses or trauma. The bony spine is commonly operated for the correction of scoliosis in paediatrics. Scoliosis is a complex spinal deformity with the potential to cause a significant cardio-pulmonary compromise. The anesthetic regimen must begin with a meticulous pre-operative evaluation and optimization. Surgery poses additional challenges such as safe positioning, maintenance of temperature and fluid balance, blood conservation and spinal cord integrity monitoring. Adequate ventilation and pain management are the primary post-operative concerns. The attending anesthesiologist has an indispensable role in addressing the major concerns and, thereby, facilitating a safe peri-operative course in the vulnerable patient cohort. The current review was drafted after searching various internet based databases carrying the detailed information related to Paediatrics spine surgery. The review is generated from the information available from full text articles downloaded from PubMed, Scopus, Science Direct, Medscape Anesthesiology, EMBASE and Google Scholar. Information was also extracted from various book chapters of clinical pediatric anesthesiology.

*Address correspondence to this author at the A-437, Sarita Vihar, New Delhi-110076; Tel: 9911573371;
E-mail: dranjugupta2009@rediffmail.com

PATHOPHYSIOLOGICAL AND FUNCTIONAL IMPAIRMENT CONSIDERATIONS

It is paramount to develop a holistic approach while evaluating the children coming for spinal surgery, with particular attention to the pulmonary, cardiovascular, and neurological systems. Functional impairment of these systems is either an association or a consequence of the pathology necessitating spinal surgery (Table **1**). The association with neuro-muscular diseases (NMD), nutritional impairment and airway difficulty should be also borne in mind.

ANESTHETIC MANAGEMENT

The state-of-the-art anesthetic management of paediatric corrective spinal surgery mandates an efficient airway management, optimal patient positioning, blood conservation and an anesthetic maintenance with minimal interference with spinal cord monitoring.

PREOPERATIVE ASSESSMENT

Preoperative assessment requires patients detailed history, thorough examination, should take into account the various associated comorbidities, syndromes and proper airway evaluation. In case of difficult intubation or unstable spinal injuries fibre-optic or other alternative methods of securing the airway to be kept in mind. Adequate investigations, especially focussing on the cardiopulmonary system should be performed. The Table **2** enlists the battery of routine and additional case base investigations for spinal surgery.

E-ISSN: 2310-9394/18

Table 1: The Functional Impairment in Various Organ Systems and their Implications

Organ Involvement	Implications
Pulmonary system Restrictive ventilatory defect Reduction is proportional to the degree (Reduced TLC, VC) of spinal deformity If VC<35% of predicted, increased need for post-operative ventilation Elevated degree of V/Q mismatch Increased propensity to cause hypoxemia	
Cardiovascular system Associated congenital heart disease prolapse Increased PVR (cardio-pulmonary interactions)	Careful pre-operative evaluation and mitral valve with a high index of suspicion Can result in RVF (cor-pulmonale)
Neurological system Pre-existing neurological deficit Proper pre-operative documentation	
Airway anomalies Syndromic associations and (VACTERL, Goldenhar syndrome) management	Careful pre-operative evaluation comprehensive airway
Nutrition Malnourishment Likely in patients with malignant disease	
Musculoskeletal system Associated neuro-muscular dystrophy Unpredictable response to muscle relaxant Respiratory impairment Increased need for post-operative ventilation	

PERI-OPERATIVE ANAESTHETIC CONSIDERATIONS

The aim to figure out the integrity of the nervous system exigencies the role of intraoperative neurophysiologic monitoring. Considering the potential of the surgical procedure to cause injury to the spinal cord, spinal nerves and nervous system, identification of subtle neurological insult under general anesthesia poses an additional constraint. Maintaining an adequate depth of anesthesia with a minimal impact on the neurophysiological monitoring is a pertinent intra-operative concern.

General anesthesia is usually preferred technique, avoiding anesthetic agent that interfere with signal acquisition. Frequently, used modalities for preventing intraoperative risk of injury is the measurement of somatosensory (SSEP) and motor evoked (MEP) potentials. Anesthetic agents usually depress amplitude and increase latencies (Table **3**). Propofol-based anesthesia is preferred over inhalation induction.

ROLE OF INTRAVENOUS ANAESTHETIC INDUCTION AGENTS

Propofol is preferred induction agent, produces a dose dependent reduction in the amplitude, but has no effect on the latency of MEPs [1]. Motor evoked potentials with multipulse stimulation provides better recordings compared with the inhalational agents nitrous oxide and isoflurane [2]. Due to its antanalgesic effect, opoids or with ketamine needs to be supplemented. The well known fact is it causes pain on injection which can be minimized by pre-or co-administration with lidocaine [3]. Propofol and remifentanil can be utilized together for total i.v. anaesthesia in older children [4].

Etomidate, usually cause adrenocortical suppression (infusion) and its use is limited to hemodynamically unstable patients [5, 6]. Thakor *et al.* l demonstrated that it augments SEP amplitude. Ketamine has the benefit to enhance the signals while monitoring evoked potentials, this can be achieved with clinically relevant doses [7]. Deeply anesthetized patient shows artificially elevated values on awareness monitors along with the use of ketamine [8]. Midazolam decreases amplitude with no effect on latency. Barbituates decreases amplitude and increases latency

BALANCING ANAESTHESIA WITH INHALATIONAL AGENTS

Nitrous Oxide

Epidural recordings of MEPs and SSEPs are less affected than both cortical SSEPs and CMAPs,as they

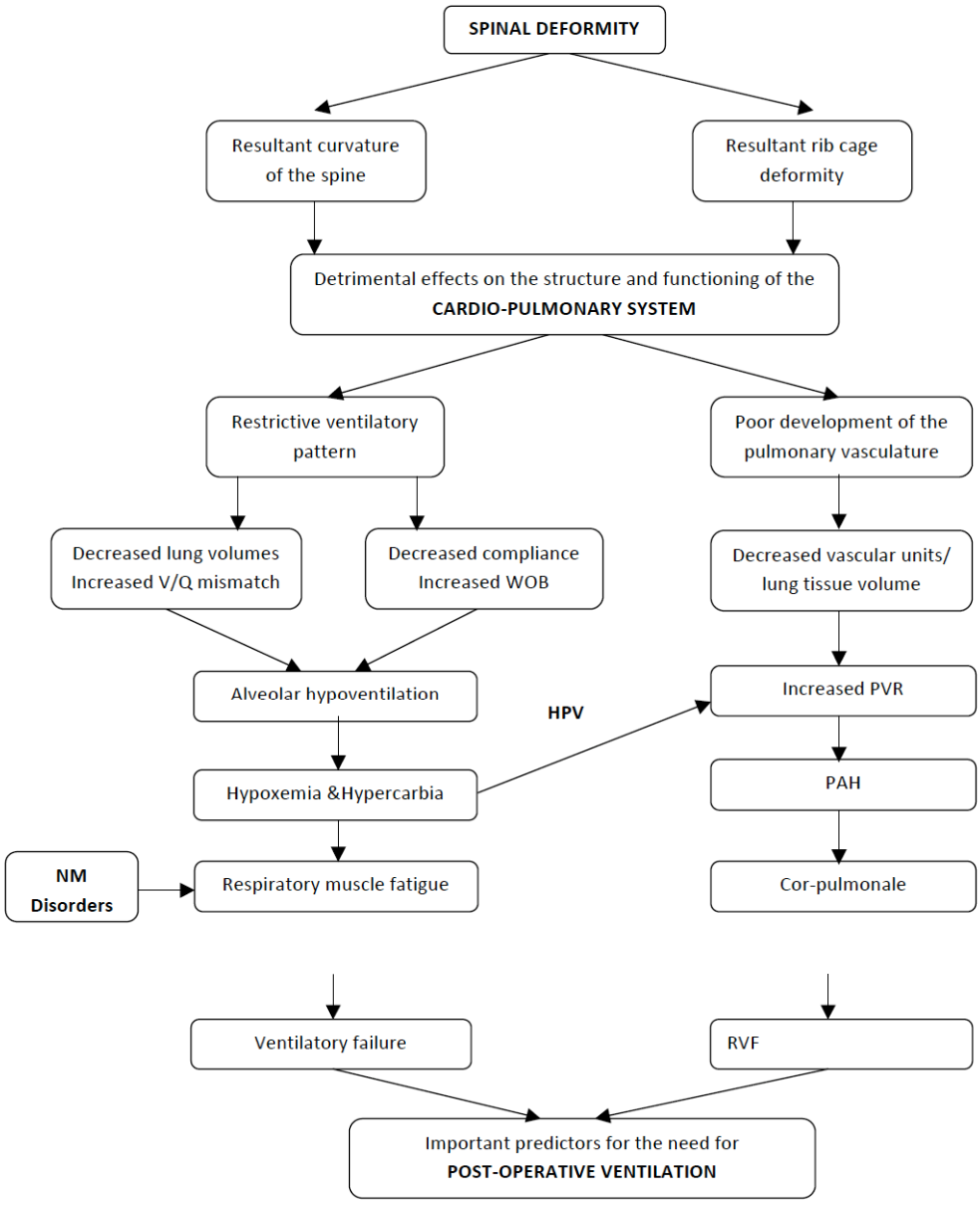

Figure 1: Pathophysiology of cardiopulmonary involvement in spinal deformity.

rely less on polysynaptic transmission. Nitrous oxide decreases cortical amplitude and increase latency of SSEPs along with propofol, opoids or used alone.

Halogenated Inhalational Agents

All halogenated inhalational agents show a dose-related increase in latency and loss of value in the amplitude of cortically recorded SSEPs, [9, 10] although, 0.5 MAC showed scanty reduction in amplitudes of the MEP than 1.0 MAC [11]. Easily titratable agents are generally recommended (sevoflurane, desflurane).

PREFERENCE OF MUSCLE RELAXANTS

Non-depolarizing neuromuscular blocking drugs are preferred over depolarizing drugs. The excellent anaesthetic technique is such that provides quiet and perpetual anaesthetic effect avoiding bolus dosing [12]. In patients with muscular dystrophy, depolarizing muscle relaxants better to be avoided in view of hyperkalemia, rhabdomyolysis and sudden cardiac arrest moreover muscle relaxants interfere more with cMAP than epidural recorded evoked potentials. Less profound muscle relaxation corresponding to 2-3 on train of four can record cMEPs [13].

Table 2:

Routine investigations	Additional investigations
Respiratory system	
Arterial blood gases	
	Spirometry, if possible
Plain chest X-ray	
Pulmonary function test FEV1 and FVC	
Cardiovascular system	
ECG	Echocardiography (non-idiopathic scoliosis)
Blood test	
Full blood count	
Coagulation profile	
Platelet function Prothrombin time , Partial thromboplastin time	
Urea and electrolytes	
Calcium and phosphate	
Blood cross –match	

BENEFITS OF OPIOID ANALGESICS

High doses of opoids, can decrease the dose requirement of propofol and volatile agents, concentration and allows reliable recording of CMAP reducing the requirement of epidural evoked potencial recordings [14]. Infusions of fentanyl, sufentanil and remifentanil have been preferred over rapid bolus doses in order to avoid marked fluctuations in recording MEPs. TIVA can be given in older children with propofol and remifentanil [4]. Loading dose of (0.5-1mcg/kg) followed by infusion of 0.2-0.5mcg/kg/h is usually administered and ended 30min before surgery is finished.

LOCAL ANESTHETICS

Lignocaine is the commonly used local anesthetic. As a part of narcotic based anesthetic, lignocaine has been shown to preserve the interpretation and waveform of SSEP while as alone it depresses the amplitude and latency [16].

Table 3: Showing Factors Affecting Somatosensory Evoked Potential

AGENT	AMPLITUDE	LATENCY
Inhalational	Decreased	Increased
Nitrous –oxide	Decreased	No effect
Propofol	No effect	No effect
Ketamine	Increased	No effect
Opoid	No effect	No effect
Barbituates	Decreased	Increased
Etomidate	Increased	No effect
Midazolam	Decreased	No effect
Hypotension	Decreased	No effect
Hypothermia	Decreased	Increased
Hypoxia	Decreased (50%)	Increased (10%)

THERMOREGULATION STRATEGIES

Children are prone to deleterious effects of temperature changes, particularly infants and neonates, although they have a unique mechanism of preventing heat loss via thermogenesis of brown fat but intraoperatively metabolic rate cannot be increased. False negative results can be observed during hypothermia [17] also there is increased latency and decreased conduction velocity where as in hyperthermia vice-versa is observed in evoked potentials. Temperature changes in either way (increased or decreased) markedly change the latency of MEPs and SSEPs so it has been advised to measure evoked potentials in a range of 2- 2.5ºc above or baseline temperature [18, 19]. Preventive measures should be taken to prevent sudden changes in temperature like warm i.v fluids, hot air blankets and warm mattresses to be used intraoperatively [20]. Operative theatre should be warm and temperature should be 27ºC.

HEMODYNAMIC MONITORING

Standard ASA monitoring should be routinely used including NIBP, ECG, $EtCO_2$, temperature probe, pulse oximetry, esophageal stethoscope, and also urine output. Dramatic blood loss contributing to hemodynamic variation may require invasive monitoring like arterial line for beat to beat monitoring or repetitive sampling and CVP, although CVP may be misleading as a guide of ventricular filling in the prone position [21].

NEUROPHYSIOLOGICAL MONITORING

Neurophysiological monitoring of spinal cord integrity is the gold standard of intraoperative care in spinal surgery [22]. The current monitoring modalities for preventing intraoperative risk of spinal cord injury are based on the measurement of somatosensory (SSEP) and motor evoked (MEP) potentials, wake up test. It is difficult to perform wake up test in small children. SSEP is generally used to predict injury to only sensory pathway, and hence there is every possible chance of motor deficit postoperatively [23]. MEP involves stimulation of motor cortex and hence both SSEPs and MEPS can be used for global spinal cord monitoring.

POSITIONING CONCERNS

Positioning the anesthetized patient prone, may cause a wide range of complications, meticulous attention to detail can prevent them. Most of the resultant neurologic injuries involves the brachial plexus (65%) followed by spinal cord injury due to neck extension 19% [24]. Overextension or flexion of the head should be avoided, eyes to be tapped properly, postoperative congestion and blindness can occur postoperatively .The arms should not be extended beyond 90º in abduction or flexion. Full length foam padding to be done to prevent injury to the genitals, peripheral nerves and other vulnerable areas. Increased abdominal pressure may reduce venous return, which result in venous congestion and increased blood loss during prone position, hence free abdominal movement should be there. Other

complications include accidental dislodgement of i.v access, monitor lines and even endotracheal tube. Overall, it requires good teamwork and attention to detail.

BLOOD CONSERVATION STRATEGIES

Dynamic hemodynamic variations and extensive nature of surgery is usually associated with drastic blood loss , even more than half of blood volume, leading to life threatening complications especially in vulnerable age group . Prolonged surgery and number of fused segments may result in coagulopathy (consumptive and dilutional) especially in the children with neuromuscular diseases [25]. The 24 hour blood loss has been estimated 200 ml/segment fused [26]. Osteopenic bone bleeds more and may have underlying coagulation abnormalities [27]. Careful monitoring of blood loss and volume status, reduces the incidence of blood transfusion.Various methods employed to reduce blood loss are discussed below;

Hypotensive anesthesia has been established as a safe and effective method for reducing blood loss up to 58% during spinal surgery [28, 29]. Mean blood pressure of 60-65 mm hg can be maintained. Severe hypotension and surgical interventions may compromise spinal cord blood, leading to neurological deficit. Alteration in spinal cord blood flow may cause loss of evoked potentials (SSEPs), especially blood flow less than 15ml/min. It is noteworthy that nowadays there is more emphasis on modalities such as antifibrinolytic therapy and cell salvage.

Pharmacological Methods of Reducing Blood Loss

There are different methods used for reducing blood loss, including Tranexamic acid, antifibrinolytics especially in patients with preexisting neurological deficit. Aprotinin was used to reduce blood loss by conserving platelet functions and inhibiting plasmin [30]. In current scenario, its use is abandoned, especially in children with repeated surgeries due to a hypersensitivity reaction and thrombotic events.

Blood Sparing Techniques

Various methods have been employed to decrease the requirement of allogenic blood transfusion Autologous blood of patients can be used pre and perioperatively. Pre-operative autologous blood donation, acute normovolemic hemodilution (ANH), Intraoperative cell salvage techniques are commonly used for decreasing allogenic transfusions [31].

Pre- Operative Blood Transfusion

In this technique, blood should be taken from patients few weeks before surgery (3-5) for using intraoperatively. Although pre donation can reduce (75%) requirement of allogeneic transfusion in lumbar fusion surgery, but it is difficult to use this method in children less than 30 kg [32].

Intraoperative Cell Salvage

Massive blood loss during surgery may necessitate the use of cell- salvage methods, it is unsuitable in case of malignancy or infection and may require replacement of clotting factors using fresh frozen plasma.

Acute Normovolemic Hemodilution

In order to prevent, loss of blood with high hematocrit, prior to surgery about 1 litre of blood is removed from the patient and is replaced by colloid/ crystalloids and replaced once hemostasis is achieved.

POSTOPERATIVE CARE

The postoperative care of paediatric patient mandates an effective analgesic and respiratory therapy. The analgesic therapy is essentially multimodal, including wound infiltration, epidural catheter placed intraoperatively by surgeons, opioids

Table 4: The façctors Predicting the Need for Post-Operative Ventilation

Spina Involvement	Organ Involvement	Surgical & Miscellaneous Factors
Cephalad involvement	Pre-existing NMD	Prolonged procedure
High cobb angle	Severe restrictive pulmonary Dysfunction (VC < 35% of predicted)	Anterior thoracic spine surgery
Number of vertebra Involved (>7)	Congenital cardiacdisese, RV failure	Blood loss > 30 ml/Kg
Obesit	Hypothermia, metabolic derangements	

(intravenous, intrathecal), patient controlled anesthesia in older children and NSAIDs. Considering the risk involved in surgery, the availability of high definition unit (HDU) becomes an essential part of postoperative care in a high risk case scenario. Various factors predicting the role of HDU have been discussed (Table **4**).

CONCLUSION

The anesthetic management of the paediatric spinal surgery has considerably evolved in the last decade. The pathophysiological consequences of the spinal pathology should dictate the peri-operative management strategy. Maintenance of a safe patient positioning, spinal cord perfusion, normothermia and normovolaemia are pivotal.Reduction in the postoperative neurological morbidity has resulted with the advent of advanced spinal cord monitoring techniques. The anesthesiologist has an important role in facilitating the efficient use of these modern techniques.The importance of dedicated post operative intensive care and multimodal analgesic therapy cannot be undermined. A meticulous peri-operative approach when combined with a good surgical correction can go a long way in improving the overall outcome after paediatric spinal surgery.

REFERENCES

[1] Nathan N, Tabaraud F, *et al.* (2003) Influence of propofol concentrations on multipulse transcranial motor evoked potentials.Br J Anaesth 91(4): 493-497. https://doi.org/10.1093/bja/aeg211

[2] Pechstein U, Nadstawek J, *et al.* (1998) Isoflurane plus nitrous oxide versus propofol for recording of motor evoked potentials after high frequency repetitive electrical stimulation. Electroencephalogr Clin Neurophysiol 108(2): 175-181 https://doi.org/10.1016/S0168-5597(97)00086-5

[3] King SY, Davis FM, *et al.* (1992) Lidocaine for the prevention of pain due to injection of propofol. Anesth Analg 74(2): 246-249. https://doi.org/10.1213/00000539-199202000-00013

[4] Eyres R. Update on TIVA. Paediatr Anaesth 2004; 14: 374-9 https://doi.org/10.1111/j.1460-9592.2004.01333.x

[5] Cohan P, Wang C, *et al.* (2005) Acute secondary adrenal insufficiency after traumatic brain injury: a prospective study. CritCare Med 33(10): 2358-2366. https://doi.org/10.1097/01.CCM.0000181735.51183.A7

[6] Wagner RL, White PF, *et al* (1984) Inhibition of adrenal steroidogenesis by the anesthetic etomidate. N Engl J Med 310(22): 1415-1421. https://doi.org/10.1056/NEJM198405313102202

[7] Erb TO, Ryhult SE, *et al* (2005) Improvement of motor-evoked potentials by ketamine and spatial facilitation during spinal surgery in a young child. Anesth Analg 100(6): 1634-1636. https://doi.org/10.1213/01.ANE.0000149896.52608.08

[8] Hans P, Dewandre PY, *et al* (2005) Comparative effects of ketamine on Bispectral Index and spectral entropy of the electroencephalogram under sevoflurane anaesthesia. Br J Anaesth 94(3): 336-340 https://doi.org/10.1093/bja/aei047

[9] Kalkman CJ, Drummond JC, *et al.* (1991) Low concentrations of isoflurane abolish motor evoked responses to transcranial electrical stimulation during nitrous oxide/opioid anesthesia in humans. Anesth Analg 73(4): 410-415. https://doi.org/10.1213/00000539-199110000-00008

[10] Zentner J, Albrecht T, *et al* (1992) Influence of halothane, enflurane and isoflurane on motor evoked potentials. Neurosurgery 31(2): 298-305 https://doi.org/10.1227/00006123-199208000-00015

[11] Sekimoto K, Nishikawa K, *et al.* (2006). The effects of volatile anesthetics on intraoperative monitoring of myogenic motorevoked potentials to transcranial electrical stimulation and on partial neuromuscular blockade during propofol/fentanyl/nitrousoxide anesthesia in humans. J Neurosurg Anesthesiol 18(2): 106-111. https://doi.org/10.1097/00008506-200604000-00003

[12] Mahla ME, Black S, Cucchiara RF. Neurologic Monitoring, Chapter 38 in Text book of Anesthesia by Miller RD, 6th edition. Elsevier Chruchill Livingstone 2005.

[13] Lang E, Beutler AS, Chesnut M, *et al.* Myogenic motor-evoked potential monitoring using partial neuromuscular blockade in surgery of the spine. Spine 1996; 21: 1676-1686. https://doi.org/10.1097/00007632-199607150-00013

[14] Lang E, Kappila A, Shlugman D, Hoke JF, Sebel PS, Glass PSA. Reduction of isoflurane minimum alveolar concentrationby remifentanil. Anesthesiology 1996; 85: 721-728. https://doi.org/10.1097/00000542-199610000-00006

[15] Guignard B, Menigaux C, Dupont X, Fletcher D, Chauvin M. The effect of remifentanil on the bispectral index change and hemodynamic responses after orotracheal intubation. Anesth Analg 2000; 90: 161-167. https://doi.org/10.1097/00000539-200001000-00034

[16] Schubert A, Licina MG, *et al* (1992) Systemic lidocaine and human somatosensory-evoked potentials during sufentanil-isoflurane anaesthesia. Can J Anaesth 39(6): 569-575. https://doi.org/10.1007/BF03008320

[17] Seyal M, Mull B (2002) Mechanisms of signal change during intraoperative somatosensory evoked potential monitoring of the spinal cord. J Clin Neurophysiol 19(5): 409-415. https://doi.org/10.1097/00004691-200210000-00004

[18] Oro J, Haghighi SS (1992) Effects of altering core body temperature on somatosensory and motor evoked potentials in rats.Spine 17(5): 498-503. https://doi.org/10.1097/00007632-199205000-00005

[19] Sakamoto T, Kawaguchi M, *et al* (2003) The effect of hypothermia on myogenic motor-evoked potentials to electrical stimulation with a single pulse and a train of pulses underpropofol/ketamine/fentanyl anesthesia in rabbits. Anesth Analg 96(6): 1692-1697 https://doi.org/10.1213/01.ANE.0000064202.24119.07

[20] Mural I, Berniere J, Constant I. Evaluation of the efficacy of forced-air warmer (Bair Hugger) during spinal surgery in children. J Clin Anesth 1994; 6: 425-9 https://doi.org/10.1016/S0952-8180(05)80016-9

[21] Soliman DE, Maslow AD, Bokesch PM et al. Transoesophageal echocardiography during scoliosis repair: comparison with CVP monitoring. Can J Anaesth 1998; 45: 925-932. https://doi.org/10.1007/BF03012298

[22] Sale F, Krzan MJ, Deletis V. Intraoperative neurophysiological monitoring in pediatric neurosurgery: why, when, how? Childs Nerv Syst 2002; 18: 264-87. https://doi.org/10.1007/s00381-002-0582-3

[23] Spielholz NI, Benjamin MV, Engler GL, *et al*. Somatosensory evoked potentials during decompression and stabilization of the spine: methods and findings. Spine 1979; 4: 500. https://doi.org/10.1007/s00381-002-0582-3

[24] Schwartz DM, Sestokas AK, *et al* (2006) Neurophysiological identification of position-induced neurologic injury during anterior cervical spine surgery. J Clin Monit Comput 20(6): 437-444. https://doi.org/10.1007/s10877-006-9032-1

[25] Horlocker TT, Nuttall GA, Dekutoski MB, Bryant SC. The accuracy of coagulation tests during spinal fusion and instrumentation. Anesth Analg 2001; 93: 33-38. https://doi.org/10.1097/00000539-200107000-00008

[26] Murray DJ, Forbes RB, Titone MB, Weinstein SL. Transfusion management in pediatric and adolescent scoliosis surgery: Efficacy of autologous blood. Spine 1997; 22: 2735-2740 https://doi.org/10.1097/00007632-199712010-00007

[27] Edler A, Murray DJ, Forbes RB. Blood loss during posterior spinal fusion surgery in patients with neuromuscular disease: is there an increased risk? Paediatr Anaesth 2003; 13: 818-822. https://doi.org/10.1046/j.1460-9592.2003.01171.x

[28] Malcolm-Smith NA, MacMaster MJ. The use of induced hypotension to control bleeding during posterior fusion for scoliosis. J Bone Joint Surg 1983; 65: 255±8. https://doi.org/10.1302/0301-620X.65B3.6841391

[29] Ulrich PF jr, Keene JS, Hogan KJ, Roecker EB. Results of hypotensive anesthesia in operative treatment of thoracolumbar fractures. J Spinal Disord 1990; 3: 329±33 .

[30] Colovic V, Walker RWM, Patel D, Rushman S. Reduction of blood loss using aprotonin in spinal surgery in children for non-idiopathic scoliosis. Paediatr Anaesth 2002; 12: 835. https://doi.org/10.1046/j.1460-9592.2002.10271_28.x

[31] Spahn DR, Casutt M. Eliminating blood transfusions: new aspects and perspectives. Anesthesiology 2000; 93: 242-255. https://doi.org/10.1097/00000542-200007000-00035

[32] DA. Raw, JK. Beattie and JM. Hunter. Anaesthesia for spinal surgery in adults British Journal of anaesthesia 2003; 91 (6): 886±904. https://doi.org/10.1093/bja/aeg253

Received on 2-12-2018 Accepted on 24-12-2018 Published on 28-12-2018

DOI: https://doi.org/10.31907/2310-9394.2018.06.1