Conference Proceeding

Challenges in paediatric neurosurgery

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Abstract

Improvements in technique, knowledge and expertise have brought about rapid advances in the fields of paediatric neurosurgery and anaesthesia, and many procedures limited earlier to adults are now being increasingly attempted in neonates and small children, with good outcomes. This article highlights the challenges faced by the operating team while handling some of the technically complex procedures like awake craniotomy, interventional neuroradiology, minimally invasive neurosurgery, procedures in intraoperative magnetic resonance imaging suites, and neonatal emergencies in the paediatric population.

Key words: Anaesthesia, awake craniotomy, intraoperative magnetic resonance imaging, neuroendoscopy, paediatric neurosurgery

INTRODUCTION

Managing small children and neonates for neurosurgery and anaesthesia is not easy, even during the familiar routine surgical procedures. Some of the challenges encountered on a daily basis in this patient population involve, securing the airway and vascular access, achieving surgical positioning, managing fluid and blood transfusions and optimal drug dosing, maintaining intraoperative haemodynamic stability, and managing large blood losses and other intraoperative complications; most of these challenges are ably met by experienced operating teams, backed by readily available relevant medical literature. However, many new technically complex neurosurgical procedures that were earlier limited to adults are now increasingly being introduced in children, and have thrown in a new set of challenges for the neurosurgeons and neuroanaesthetists. This review focusses on these relatively recent paediatric neurosurgeries and highlights the complexities of perioperative care in them.

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AWAKE CRANIOTOMY IN PAEDIATRIC PATIENTS

Awake craniotomy (AC) is performed for tumours and seizure foci near or within the eloquent cortex and involves the use of intraoperative cortical mapping for identifying speech and motor areas by testing the motor, sensory and language functions and verbal memory in an awake and responsive patient. Some of the main concerns during AC are airway compromise due to over-sedation, patient non-cooperation due to anxiety, pain and restlessness, onset of seizures, patient injuries such as scalp lacerations and skull and cervical spine fractures in a convulsive or agitated patient fixed in head pins, need for conversion to general anaesthesia (GA) due to poor brain operating conditions

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or non-cooperation, haemodynamic instability and respiratory insufficiency.[1]

Proper patient selection is vital to the success of an AC. A thorough understanding of the procedure by the patient and good communication and coordination between the patient and operating team are essential. Although a well-established technique in adults, AC is a challenging prospect in paediatric patients due to their lower levels of cognitive development and emotional maturity, and higher levels of anxiety, increasing the chances of intraoperative patient non-compliance. AC is thus relatively contraindicated in younger (<11–12 years) and emotionally immature children and also in developmentally delayed children and those with severe anxiety or psychiatric disorders.[1] However, AC has been reported for glioblastoma surgery under propofol sedation in a 9-year-old boy; the youngest candidate by far.[2] Pre-operative preparation must include a thorough discussion among the neurosurgeons, neurologists, neuro-anaesthetists, the patient and his/her parents regarding the procedure and the responses expected from the child during cortical mapping. Extra efforts should be made towards psychological preparation of the child by building a good rapport and trust between the child and the operating team and to adequately address the child's concerns and fears.[1,2]

Among the various anaesthetic approaches currently used for adults, the 'fully awake' technique should only be limited to a mature, motivated and cooperative child, since all the tasks such as insertion of intravenous/arterial lines and urinary catheter placement, local anaesthesia (LA) infiltration, head pins fixation and cortical mapping have to be done in the awake state.[3] The technique using short-acting sedatives and analgesics (propofol, fentanyl) is better for facilitating surgery as well as cortical stimulation in a spontaneously breathing child.[2,4] The use of dexmedetomidine[5,6] and remifentanil-propofol[7] has also been described for AC. The asleep-awake-asleep technique uses GA and a supraglottic device insertion in the beginning and end of the procedure and an awake state without the device during the mapping part. Although it reduces the stress in children, this method has intraoperative disadvantages such as airway obstruction, patient injuries and brain swelling.[8] Special care must be taken to adjust the doses of sedatives/analgesics, and of LA drugs for scalp block and skin infiltration, and to obtain the most comfortable position for the procedure that may last several hours. Reduction of intra-procedural anxiety and confusion in children is very challenging, and for this, maintenance of continuous, close visual and verbal communication between the anaesthesiologist and the child is vital. Currently, there are only isolated reports on the use of AC in children,[2-8] and randomised, controlled trials would be required to ascertain its actual effectiveness and safety in the paediatric population.

NEURO-INTERVENTIONAL PROCEDURES IN PAEDIATRIC PATIENTS

Diagnostic imaging and therapeutic interventions carried out in the interventional neuroradiology (IR) suite are being used more frequently for treating neurovascular diseases in children.[9] Paediatric cerebral angiography is the most common neuro-interventional procedure in children and is mostly reserved for cases where computed tomography (CT) or magnetic resonance (MR) angiography provides insufficient information. Usual indications include, stroke from Moyamoya disease or other causes, haemorrhage and post-operative evaluation of cerebrovascular treatment.[10-12]

Perioperative care of small children in the IR suite is challenging; these patients are often sick, are administered GA in a remote, non-operating room (OR) setting which may have older equipment and less experienced anaesthesiologists, and the procedures are usually long and complex. Femoral arterial catheterisation is followed by advancement of the catheter into the carotid or vertebral arteries, and angiography is performed using apnoea spells of 10–20 s. After completion of imaging and removal of the arterial sheath, the groin is kept pressed for 15–20 min till bleeding stops, and the patient is kept on flat bed rest in the recovery room to assist haemostasis.[9,12] GA is used in small children, while older, mature patients can be given sedation and anxiolysis; however, deeper levels of sedation in children may not permit breath holding required for the angiography runs.[13] Perioperative considerations include, management of blood pressure, fluid and post-operative care; maintaining euvolaemia or slight hypervolemia throughout helps reduce the chances of kidney damage in children due to contrast-induced osmotic diuresis.[9] Achieving flat bed rest in children to assist post-procedural haemostasis is not easy. Reassurance, distraction and presence of parents are important behaviour techniques in older children while the younger patients may be given sedatives, though cautiously. Deep-level extubation aided by narcotics or clonidine[14] helps in keeping the children calm in the post-operative period. Cerebral angiography series in paediatric patients have reported complication rates of <0.4%,[10,11,13] of which bleeding at the femoral puncture site is the most common.[15] The risk of acute contrast allergic reactions is <1%;[16] neurologic and vascular complications are also very low in children.

The commonly performed neuroendovascular interventions in children include, embolisation of intracerebral, vascular anomalies such as, arteriovenous malformations (AVMs), arteriovenous fistulae, aneurysms and intra-arterial chemotherapy for tumours.[17-20] These long procedures are always performed in children under GA and muscle relaxation. Most part of the procedure is similar to that in adults; however, special precautions must be taken to prevent fluid overload through the continuous heparinised saline infusion, hypothermia from the cold OR environment and body exposure and heparin overdosage due to miscalculation. Balloon-assisted glue embolisation is preferred over measures such as deliberate hypotension or induced asystole to facilitate glue injection or coil placement into a high-flow lesion in paediatric patients. Complications such as ruptured intracranial vessel (incidence of <0.5% of cases)[12] and migration of embolic material (incidence 3%) are reported[21] in children. Injection of intra-arterial chemotherapy may also be associated with complications such as bronchospasm and post-operative nausea and vomiting which may create problems for children who are required to lie flat for groin haemostasis.

NEUROSURGERY IN THE INTRAOPERATIVE MAGNETIC RESONANCE IMAGING SUITES IN PAEDIATRIC PATIENTS

Intraoperative MR imaging (iMRI) allows improved intraoperative navigation and quality of resection of intracranial masses and is increasingly being used for paediatric neurosurgical procedures. Used with a frameless navigation system, the iMRI helps localise the lesions and also improve the quality and pseudo real-time assessment of resection during neurosurgery.[22-24] The procedure requires the use of MRI-safe equipment, which may have some limitations; the pulse oximeter, electrocardiograph and temperature monitoring may develop movement artefacts. Equipment such as forced-air warming devices, nerve stimulators, fluid warmers and precordial Doppler probes may not be MRI compatible and need to be removed at the time of imaging. The existence of a movable high-strength magnetic field in iMRI, unlike the stationary field in diagnostic MRI, presents unique challenges for the anaesthesia and surgical team.[25] Indications for the use of iMRI in children include, facilitation of intracranial tumour resection, delineation of the extent of cortical disconnection in major seizure surgery like corpus callosotomy or functional hemispherectomy and thermal ablation of deep brain lesions.[26,27] Absolute contraindications to iMRI include, children with implantable devices such as, pacemakers and defibrillators, vagal nerve stimulators and programmable ventricular shunt valves; the relative contraindications include, neonates and small children who may not tolerate lengthy procedures under GA in a cold environment and bulky/obese children who may face positioning problems inside the magnet. Hence, iMRI surgery in children <10 kg or 1 year of age is best avoided. The basic approach, anaesthetic technique and post-operative care of children in iMRI suite are almost similar to that in a conventional OR. The need for doing a post-operative MRI in children, that would require a repeat GA, is obviated after iMRI which can help detect serious post-operative complications such as intracranial bleeding before the child deteriorates clinically.

MINIMALLY INVASIVE PAEDIATRIC NEUROSURGERY

Improved imaging, navigation and endoscopy have allowed extension of minimally invasive neurosurgeries (MIN) to the paediatric age group.[28-30] These procedures were introduced many years back, but with newer indications being added periodically, the MIN techniques are continuously evolving. MIN permits decreased brain tissue disruption, incision size, post-operative pain and patient recovery period. The procedure involves the following steps and components, (1) precise identification of the lesion using CT, MRI, functional MRI, (2) development of specific operative approach with the help of computerised frameless stereotactic navigation systems, intraoperative ultrasound or intraoperative CT/MRI, (3) augmentation of field of vision and provision of adequate lighting using the neuroendoscope and (4) display of a high-definition image of operative field with the help of digital video technology. The minimally invasive approach in paediatric patients is mostly used in surgeries for hydrocephalus, arachnoid cysts, some intracranial masses and craniosynostosis.[31-33]

Shunts inserted for hydrocephalus are known to be associated with many complications and nearly 40%–50% of shunts may fail within 2 months of insertion, especially in neonates. The endoscopic third ventriculostomy (ETV) method for treating obstructive hydrocephalus involves fenestration of floor of the third ventricle, allowing an alternate outlet for the cerebrospinal fluid (CSF) flow. Arachnoid cysts are treated by endoscopic fenestration of the cyst wall that allows the CSF to flow out through normal pathways. The procedures are challenging as they require surgical precision and expertise, and if not done carefully, may cause several complications, the most significant being permanent neurological deficits secondary to injuries to vital structures such as hypothalamus, brainstem and cranial nerves and massive haemorrhage from basilar artery rupture. Success rates for surgery are

90% and above in older children with obstructive hydrocephalus and no prior shunt and is very low in neonates with post-infectious hydrocephalus and prior shunting; most complications occur within 6 months of the procedure. ETV is best avoided in children below 1 year. Anaesthetising very small children is challenging; the main anaesthetic focus is on maintaining haemodynamic stability, fluid-electrolyte balance and normothermia and ensuring intraoperative patient immobility, but at the same time, rapid post-operative awakening after the relatively smaller procedures.[34]

Intracranial mass lesions treated by the transventricular endoscopic route include, pineal and thalamic tumours and hypothalamic hamartomas.[32] The nasal transsphenoidal route is used for lesions of sella turcica and cribriform plate and some paramedian posterior fossa tumours. The relatively smaller nasal cavities in children and requirement for smaller instrumentation make this surgical approach challenging. Strip craniectomy and cranial remodelling operations required for craniosynostosis correction should ideally be done as early as possible for best results. However, performing them in neonates and young infants is challenging due to the associated significant blood losses and potential for venous air embolism (VAE). The minimally invasive approach of endoscopic strip craniectomy, indicated in children <2 months of age, has reduced the morbidity in neonates and young children by reducing blood loss, surgical time and incidence of VAE,[35] and caused a better post-operative recovery.[36] Endoscopic excision of the fused sutures followed by post-operative reshaping with cranial moulding helmets can also be done in small children.

NEUROSURGICAL EMERGENCIES IN NEONATES

Neurosurgery in neonates has been around for many decades, but deserves a special mention here as it continues to be one of the most challenging procedures. Wherever possible, surgery should be deferred till the child is more mature. Hydrocephalus, meningomyeloceles or encephaloceles, however, may require surgery on an emergency basis. The perioperative morbidity and mortality is 10-fold higher in neonates compared to older children. Major causes of the enhanced surgical risks in neonates include their relatively underdeveloped multi-organ function resulting in poor respiratory and cardiac reserves, immature liver and kidney functions and inability to handle large blood and fluid-electrolyte losses and hypothermia, low immunity levels and co-existence of various anatomical and physiological abnormalities such as, concomitant congenital anomalies, persistent transitional circulation in premature neonates, large cerebral AVMs and intracranial right to left shunting due to patent ductus arteriosus or foramen ovale. A dedicated and experienced team of paediatric neurosurgeons and anaesthetists is thus warranted for the safe and effective management of neurosurgical emergencies in neonates.

CONCLUSION

Management of paediatric neurosurgical patients is a major challenge for the neurosurgeons and anaesthetists, particularly with the introduction of some of the relatively recent, technically complex procedures in neonates and small children. A good understanding of age-dependant variables and effects of anaesthetic and surgical procedures on the paediatric population are essential in minimising the perioperative morbidity and mortality.

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REFERENCES

1. McClain CD, Landrigan-Ossar M. Challenges in pediatric neuroanesthesia: Awake craniotomy, intraoperative magnetic resonance imaging, and interventional neuroradiology. Anesthesiol Clin 2014;32:83-100.
2. Klimek M, Verbrugge SJ, Roubos S, van der Most E, Vincent AJ, Klein J. Awake craniotomy for glioblastoma in a 9-year-old child. Anaesthesia 2004;59:607-9.
3. Hansen E, Seemann M, Zech N, Doenitz C, Luerding R, Brawanski A. Awake craniotomies without any sedation: The awake-awake-awake technique. Acta Neurochir (Wien) 2013;155:1417-24.
4. Soriano SG, Eldredge EA, Wang FK, Kull L, Madsen JR, Black PM, *et al.* The effect of propofol on intraoperative electrocorticography and cortical stimulation during awake craniotomies in children. Paediatr Anaesth 2000;10:29-34.
5. Ard J, Doyle W, Bekker A. Awake craniotomy with dexmedetomidine in pediatric patients. J Neurosurg Anesthesiol 2003;15:263-6.
6. Everett LL, van Rooyen IF, Warner MH, Shurtleff HA, Saneto RP, Ojemann JG. Use of dexmedetomidine in awake craniotomy in adolescents: Report of two cases. Paediatr Anaesth 2006;16:338-42.
7. Keifer JC, Dentchev D, Little K, Warner DS, Friedman AH, Borel CO. A retrospective analysis of a remifentanil/propofol general anesthetic for craniotomy before awake functional brain mapping. Anesth Analg 2005;101:502-8.
8. Hagberg CA, Gollas A, Berry JM. The laryngeal mask airway for awake craniotomy in the pediatric patient: Report of three cases. J Clin Anesth 2004;16:43-7.
9. Landrigan-Ossar M, McClain CD. Anesthesia for interventional radiology. Paediatr Anaesth 2014;24:698-702.
10. Burger IM, Murphy KJ, Jordan LC, Tamargo RJ, Gailloud P. Safety of cerebral digital subtraction angiography in children: Complication rate analysis in 241 consecutive diagnostic

angiograms. Stroke 2006;37:2535-9.
11. Robertson RL, Chavali RV, Robson CD, Barnes PD, Eldredge EA, Burrows PE, *et al.* Neurologic complications of cerebral angiography in childhood moyamoya syndrome. Pediatr Radiol 1998;28:824-9.
12. Alexander MJ, Spetzler RF. Pediatric Neurovascular Disease: Surgical, Endovascular and Medical Management. New York: Thieme; 2006.
13. Wolfe TJ, Hussain SI, Lynch JR, Fitzsimmons BF, Zaidat OO. Pediatric cerebral angiography: Analysis of utilization and findings. Pediatr Neurol 2009;40:98-101.
14. Malviya S, Voepel-Lewis T, Ramamurthi RJ, Burke C, Tait AR. Clonidine for the prevention of emergence agitation in young children: Efficacy and recovery profile. Paediatr Anaesth 2006;16:554-9.
15. Gross BA, Orbach DB. Addressing challenges in 4 F and 5 F arterial access for neurointerventional procedures in infants and young children. J Neurointerv Surg 2014;6:308-13.
16. Dillman JR, Strouse PJ, Ellis JH, Cohan RH, Jan SC. Incidence and severity of acute allergic-like reactions to i.v. nonionic iodinated contrast material in children. AJR Am J Roentgenol 2007;188:1643-7.
17. Thiex R, Williams A, Smith E, Scott RM, Orbach DB. The use of Onyx for embolization of central nervous system arteriovenous lesions in pediatric patients. AJNR Am J Neuroradiol 2010;31:112-20.
18. Walcott BP, Smith ER, Scott RM, Orbach DB. Dural arteriovenous fistulae in pediatric patients: Associated conditions and treatment outcomes. J Neurointerv Surg 2013;5:6-9.
19. Saraf R, Shrivastava M, Siddhartha W, Limaye U. Intracranial pediatric aneurysms: Endovascular treatment and its outcome. J Neurosurg Pediatr 2012;10:230-40.
20. Shields CL, Bianciotto CG, Jabbour P, Ramasubramanian A, Lally SE, Griffin GC, *et al.* Intra-arterial chemotherapy for retinoblastoma: Report No 1, control of retinal tumors, subretinal seeds, and vitreous seeds. Arch Ophthalmol 2011;129:1399-406.
21. Ledezma CJ, Hoh BL, Carter BS, Pryor JC, Putman CM, Ogilvy CS. Complications of cerebral arteriovenous malformation embolization: Multivariate analysis of predictive factors. Neurosurgery 2006;58:602-11.
22. Nimsky C, Ganslandt O, Gralla J, Buchfelder M, Fahlbusch R. Intraoperative low-field magnetic resonance imaging in pediatric neurosurgery. Pediatr Neurosurg 2003;38:83-9.
23. Cox RG, Levy R, Hamilton MG, Ewen A, Farran P, Neil SG. Anesthesia can be safely provided for children in a high-field intraoperative magnetic resonance imaging environment. Paediatr Anaesth 2011;21:454-8.
24. McClain CD, Rockoff MA, Soriano SG. Anesthetic concerns for pediatric patients in an intraoperative MRI suite. Curr Opin Anaesthesiol 2011;24:480-6.
25. Levy R, Cox RG, Hader WJ, Myles T, Sutherland GR, Hamilton MG. Application of intraoperative high-field magnetic resonance imaging in pediatric neurosurgery. J Neurosurg Pediatr 2009;4:467-74.
26. Curry DJ, Gowda A, McNichols RJ, Wilfong AA. MR-guided stereotactic laser ablation of epileptogenic foci in children. Epilepsy Behav 2012;24:408-14.
27. Tovar-Spinoza Z, Carter D, Ferrone D, Eksioglu Y, Huckins S. The use of MRI-guided laser-induced thermal ablation for epilepsy. Childs Nerv Syst 2013;29:2089-94.
28. Governale LS. Minimally invasive pediatric neurosurgery. Pediatr Neurol 2015;52:389-97.
29. Meier PM, Goobie SM, DiNardo JA, Proctor MR, Zurakowski D, Soriano SG. Endoscopic strip craniectomy in early infancy: The initial five years of anesthesia experience. Anesth Analg 2011;112:407-14.
30. Navarro R, Gil-Parra R, Reitman AJ, Olavarria G, Grant JA, Tomita T. Endoscopic third ventriculostomy in children: Early and late complications and their avoidance. Childs Nerv Syst 2006;22:506-13.
31. Maher CO, Goumnerova L. The effectiveness of ventriculocystocisternostomy for suprasellar arachnoid cysts. J Neurosurg Pediatr 2011;7:64-72.
32. Ahmad F, Sandberg DI. Endoscopic management of intraventricular brain tumors in pediatric patients: A review of indications, techniques, and outcomes. J Child Neurol 2010;25:359-67.
33. Berry-Candelario J, Ridgway EB, Grondin RT, Rogers GF, Proctor MR. Endoscope-assisted strip craniectomy and postoperative helmet therapy for treatment of craniosynostosis. Neurosurg Focus 2011;31:E5.
34. Johnson JO, Jimenez DF, Tobias JD. Anaesthetic care during minimally invasive neurosurgical procedures in infants and children. Paediatr Anaesth 2002;12:478-88.
35. Tobias JD, Johnson JO, Jimenez DF, Barone CM, McBride DS Jr. Venous air embolism during endoscopic strip craniectomy for repair of craniosynostosis in infants. Anesthesiology 2001;95:340-2.
36. Jimenez DF, Barone CM, Cartwright CC, Baker L. Early management of craniosynostosis using endoscopic-assisted strip craniectomies and cranial orthotic molding therapy. Pediatrics 2002;110(1 Pt 1):97-104.