The Internet Journal of Anesthesiology
Volume 30 Number 1

Anaesthetic Management Of Patients With Acute Spinal Injury

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Citation

V Wirasinghe, S Grover, D Ma, M Vizcaychipi. *Anaesthetic Management Of Patients With Acute Spinal Injury*. The Internet Journal of Anesthesiology. 2010 Volume 30 Number 1.

Abstract

Acute Spinal Injury (ASI) is relatively rare, presenting most frequently in young male adults. The commonest cause of spinal injury is road traffic accidents, followed by domestic, industrial and sporting injuries. Self-harm and assault count for less than 10% of the cases. A high index of suspicion of spinal injury and timely, safe intervention is important in multiple trauma patients and where the mechanism of injury is suggestive of ASI. The anaesthetist, in encountering these patients at several points in their hospital management, has an important role in optimal care of ASI. The choice of anaesthetic technique and intervention, together with the timing of intervention, must be carefully considered. The aim is to protect the spinal cord from further damage, avoid further disruption in alignment, and facilitate stability of the vertebral column to permit maximal neurological recovery and rehabilitation.

INTRODUCTION

Spinal injury is relatively rare, presenting most frequently in young male adults. The commonest cause of spinal injury is road traffic accident, followed by domestic, industrial and sporting injuries [1]. Self-harm and assault account for less than 10% of cases [2 3]. The incidence of other conditions causing ASI such as inflammatory, neoplastic and infective conditions is currently unknown.

Traumatic spinal cord injury in the United Kingdom affects an estimated 10–15 people per million population per year and there are around 40,000 individuals in the UK living with a traumatic spinal cord injury. In comparison, the incidence in the United States lies between 50 and 55 people per million population per year [4].

A delay in diagnosis or inappropriate handling may aggravate primary injury and lead to the development of secondary spinal injury [5], thereby increasing morbidity and mortality [6 7].

Acute cervical spinal injury accounts for one third to a half of total spinal cord injuries [1]. Cervical spine injury causes significant morbidity and mortality, and has a large economic impact in both the acute and convalescent phases [8]. The incidence of cervical spine injury varies in different countries but in the western world it is reported to be around 1.5%–4% [9] in the setting of major trauma [10 11 12]. In patients with a GCS of less than 8 or focal neurology the chances of having a cervical spinal injury are greatly increased [13 14]. This makes it imperative to consider cervical spinal injury in the setting of traumatic brain injury. Equally, spinal injury must be considered in facial trauma, as there is evidence to indicate 6-7% of facial trauma patients have a concomitant cervical spinal injury [15 16]. Isolated cervical spinal injuries are uncommon, with injuries being restricted to the cervical spine in less than a fifth of patients[17].

The key aim of spinal cord injury management is to prevent secondary damage and preserve residual neurological function, with intent to restore spinal alignment and stability, and achieve maximal neurological recovery.

DEVELOPMENT OF TECHNIQUES FOR MANAGEMENT OF ACUTE SPINAL INJURY

Early treatment of spinal injuries consisted of prolonged bed rest, which has been linked to multiple foreseeable complications. These include respiratory complications (pneumonia, atelectasis), sepsis, deep venous thrombosis, genitourinary (renal stones, urinary tract infections), gastrointestinal (impaired glucose tolerance, constipation), pressure sores and ischaemic ulcers[18 19].

By the seventh century A.D., Paulus of Aegina was recommending surgery for spinal column fracture to remove the bone fragments that he was convinced caused paralysis.

In his influential anatomy textbook published in 1543, the Renaissance physician and teacher Vesalius described and illustrated the spinal cord in all its parts. The illustrations in his books, based on direct observation and dissection of the spine, provided physicians with a means of understanding the basic structure of the spine and spinal cord and consequences of injury. Terminology we use today to identify segments of the spine - cervical, thoracic, lumbar, sacral, and coccygeal - come directly from Vesalius.

The development and uptake of antisepsis and sterilization in the late nineteenth century meant spinal surgery could finally be done with a much lower risk of infection. The development and use of X-rays around the 1920s, gave surgeons a means of precisely locating and classifying injury, and also improved accuracy of diagnosis and prediction of prognosis.

By the mid-twentieth century, a standard method of treating spinal cord injuries was established. It involved repositioning the spine, fixing it in place, and rehabilitation with exercise [20]. Prompt surgical intervention appeared to reduce rehabilitation time. In 1990, evidence that methylprednisolone could reduce damage to nerve cells if given early enough after acute spine trauma gave doctors an additional treatment option (NASCIS III)[21]. However, clinical series over a number of years with varied treatment regimens have failed to show a significant improvement in neurological outcome [4].

THE ANAESTHETIST IN THE MANAGEMENT OF SPINAL INJURY

There is now good evidence that “all is not lost” with the initial primary injury. The spinal cord may suffer further biochemical and pathological changes consequent to the primary insult [22 23], and this secondary injury is amenable to prophylaxis and treatment.

Anaesthetists often encounter patients at their initial resuscitation phase after acute spinal cord injury. Therefore, they are in ideally placed to influence the degree of functional recovery that may take place. Anaesthesia at this stage may be mandated for stabilization, patient transfer, and intervention to include imaging and the surgical management of life-threatening injury.

A secondary phase of management of patients with ASI follows. This may include the provision of anaesthesia for radiological investigation or delayed surgical intervention to manage the ASI and/or associated injuries. Anaesthetic input in this phase also features in patient transfer and the management of some of these patients on the Intensive Care Unit (ICU).

In the long term, the anaesthetic team may be involved in multiple visits to theatre for the long-term management of ASI and associated injury, and the presentation of these patients for unrelated surgery or pain management.

Figure 1

Table 1: Summary Anaesthetic Management of Acute Spinal Injury

Phase	Key Issues
Primary Phase – Initial Resuscitation	High index of suspicion in at-risk groups- trauma/ paediatric/ geriatric ATLS priorities : • Airway with cervical spine immobilization • Breathing • Circulation with haemorrhage control Neurogenic shock management
Secondary Phase – Anaesthetic	• Secure airway • Oxygenation • Normocapnoea • Normoglycaemia • Spinal Cord Perfusion: Fluid management/ Inotropes/ Vasopressors/ Cerebrospinal fluid drainage • Monitoring: Arterial cannula/ Central Venous Cannula/ Urine output/ Cardiac output/ Sensory or Motor Evoked Potentials • Fluid Management: Antifibrinolytic agents/ Managing Coagulopathy/ Cell Salvage • Consider Steroids
Secondary Phase – Intensive Care	• Attention to infection control • Early establishment of feed • Thromboprophylaxis/ minimize immobilization • Concomitant head injury management • Monitor for progression of spinal cord injury • Monitor for evidence of infection/ organ failure
Long-term	• Multiple hospital admissions/ anaesthetics & risk of multi-drug resistant organisms • General vs. Regional anaesthesia • Autonomic nervous system dysfunction • Patient positioning under anaesthesia • Potential Difficult Airway • Pain Management

PRIMARY PHASE - INITIAL RESUSCITATION

This phase includes resuscitation in casualty, typically airway management with protective cervical spine precautions, breathing, circulation and primary survey. A high index of suspicion of spinal cord injury should always be maintained in multiple trauma patients as up to 10 percent may have spinal injury. The groups particularly at risk include those with traumatic brain injury, facial trauma, patients presenting with low GCS, paediatric and geriatric patients [24 15 16]. Neurogenic shock, characterized by flaccid paralysis of voluntary muscles, areflexia, loss of sympathetic tone (hypotension and bradycardia, increased vascular capacitance), poikilothermia and flaccidity of the gastrintestinal tract and the bladder with generalized ileus and urinary retention may be a presentation of injury, particularly in high thoracic or cervical injuries.

Traumatic ASI is associated with a reduction in local spinal blood flow and loss of autoregulation leading to ischaemia and tissue hypoxia. Superimposed on this background, injured neural tissue is particularly vulnerable to hypoxaemia and hypotension, and may undergo further secondary damage. Hence, the first and probably most important step in resuscitating the injured spinal cord, together with immobilizing the spine, is to correct hypotension and hypoxaemia.

The fully conscious patient is able to maintain his own airway and needs no further airway manipulation. However, the patient's status may deteriorate at any time, and so must constantly be reassessed. Airway management in those with a depressed or fluctuating level of consciousness can be challenging, and senior help should be sought early. Techniques for airway management and securing a definitive protected airway will be discussed later. Once the airway has been secured, the focus is on adequate oxygenation and ventilation to normocapnoea.

Immobilization of the cervical spine prior to radiographic assessment is the accepted standard of care for multiple trauma patients. The rationale behind early immobilization is the avoidance of exacerbation of neurological injury in patients with an unstable spine. The availability of multiple devices and techniques implies the absence of one single device offering a gold standard for spine immobilization[25-27].

Maintaining adequate spinal perfusion pressure is paramount. Anaesthetic agents, if employed at this stage, must be selected primarily on this basis (Table 1). Monitoring and investigations at this stage should include, at a minimum, continuous ECG, pulse oximetry, regular blood pressure measurement, capnography and blood testing for arterial pCO_2, haemoglobin, glucose, electrolytes, and coagulation. The circumstances of presentation may indicate the inclusion of screening blood and urine specimen for toxins.

SECONDARY PHASE - ANAESTHESIA

This includes administration of anaesthesia for stabilisation of the spinal column and also surgical management of associated injuries. Spinal surgery is generally performed to treat either nerve/spinal cord impingement (decompression surgery) or spinal instability (fusion surgery). The two procedures are often combined, as decompression may de-stabilise the spine and create the need for fusion to add stability. This helps to prevent and protect the spinal cord from further damage, to maintain alignment of the bony structures to allow maximal recovery in incomplete lesions and to achieve stability of the bony column to allow rehabilitation.

The timing of anaesthetic, and prioritisation of injury management, in a multidisciplinary manner is crucial to optimal recovery. Once again, the selection of airway management technique and anaesthetic agents must be carefully considered. All anaesthetic drugs that decrease cerebral metabolic rate seem to have some protective effect.

Invasive monitoring to include central venous cannulation, arterial line insertion, urine output monitoring and cardiac output monitoring, e.g. Oesophageal Doppler, may be indicated for fluid and vasoactive drug management. Spinal cord monitoring perioperatively has been advocated in patients who have suffered vertebral column injuries to monitor neurological function during and after surgical intervention. Total intravenous anaesthesia allows motor and sensory monitoring throughout maintenance of anaesthesia. Motor evoked potentials are suppressed by volatile anaesthetics in a dose-dependant manner [28]. Total intravenous anaesthesia allows motor and sensory monitoring throughout maintenance of anaesthesia.

Adequate oxygenation, normocapnoea, normoglycaemia are paramount as derangement of these variables may lead to irreversible secondary damage. The main goal during maintenance of anaesthesia is to maintain adequate spinal cord perfusion to prevent further damage. If there is loss of autoregulation, spinal perfusion becomes dependent on systemic perfusion. Systemic hypotension may therefore cause secondary injury by reducing spinal perfusion pressure. Conversely, hypertension may lead to haemorrhage and oedema. Drainage of cerebrospinal fluid via a catheter may also be considered to help improve spinal perfusion pressure.

There is little evidence regarding targeted blood pressures and the duration of support required to improve outcome in the injured spinal cord [29]. The American Association of Neurological Surgeons [30] published recommendations for the haemodynamic goals for a spinal cord injury patient. These include maintaining mean arterial pressure of 85-90 mmHg and avoiding systolic blood pressures less than 90 mmHg for over 5-7 days. Judicious use of intravenous fluids, vasopressors and inotropes is advisable to target these parameters.

Perioperative fluid management in the patient with acute spinal cord injury can be challenging. The potential for significant blood loss with spinal surgery, together with blood loss and cardiovascular instability from other injury, may present the anaesthetist with multiple factors to consider in managing fluid, inotropic and vasopressor support. Excessive fluid administration in the prone patient is associated with significant oedema (including airway oedema), cardiac failure, electrolyte abnormalities, coagulopathy and prolonged duration of postoperative intensive care unit stay [31]. Goal-directed fluid management, minimizing blood loss and correction of coagulopathy minimize these risks.

Strategies to minimize intraoperative blood loss include the use of anti-fibrinolytic agents such as aminocaproic acid and tranexamic acid. These have been shown to reduce blood loss without an increase in thromboembolic complications [32 33]. A single small study indicated recombinant Factor VIIa significantly reduces blood loss[34]. However, none of the studies showed a significant reduction in transfusion requirements.

Further strategies to minimize blood product transfusion include surgical attention to haemostasis and careful ongoing management of coagulopathy. This involves the use of rapid, point-of-care tests (e.g. HemoCue, Thromoelastography) and laboratory testing (Prothrombin time, Fibrinogen, Platelet counts, Haemoglobin) to guide use of transfusion products [35]. Cell salvage and autologous transfusion has little data in this population to make an evidence-based recommendation for its routine use. A recent systematic review concluded that there is little in the literature to support the cost-effective use of cell saver in routine elective spine surgery [36].

High dose steroids had been thought to be paramount in the management of acute spinal injury (NASCIS III), but the CRASH trial showed that steroids worsened outcome after head injury. The NASCIS studies were underpowered and also revealed an increased risk of serious side effects including wound infections, steroid myelopathy and gastrointestinal haemorrhage with high dose methylprednisolone [37]. This topic remains controversial and the use of steroids depends on the treating clinician.

SECONDARY PHASE – INTENSIVE CARE

A large number of patients with cervical spinal injury have associated other injuries and are nursed in the intensive care unit (ICU). A proportion of these have had traumatic brain injury and raised intra cranial pressure (ICP). It is imperative to prevent any further rise in ICP until swelling associated with diffuse brain injury subsides, or is surgically decompressed. An urgent exclusion of cervical spine injury in such patients should be undertaken to safely remove hard collars that can impair venous drainage and contribute to raised ICP.

Respiratory management to prevent or treat chest complications must be developed in conjunction with a chest or neurophysiotherapist [18]. This may include clearing of airway secretions by assisted coughing, suctioning (risk of bradycardia induced by suction). Re-expansion of affected lung may involve deep breathing, positioning, positive pressure ventilation, bronchoscopy with lavage and mucolytic medication.

Prolonged ICU or ward-based care of these patients require the institution of critical care bundles that facilitate early establishment of nutrition, attention to infection control and pressure areas. The role of good nursing care cannot be overemphasized in determining the outcome of these patients. Prolonged immobilization of patients in ICU predisposes to deep vein thrombosis. Prophylaxis by mechanical (graduated compression stockings, calf compression devices, inferior vena caval filters) or pharmacological systemic anticoagulation should be instituted where not contraindicated. Immobilisation should also be minimized to prevent the development of secondary musculoskeletal wasting and contractures [19].

LONG-TERM MANAGEMENT

This includes administration of anaesthesia in the long-term management of the patient with ASI for related and unrelated surgical procedures.

The issues of an unstable cervical spine may dictate that a regional technique is preferable. Equally, fixation or stabilisation devices within the bony column may preclude central neuraxial techniques of anaesthesia. Fixed deformities and contractures have added consequences on airway management, intravenous access sites and patient positioning.

Autonomic nervous system dysreflexia as a result of spinal injury must be considered in planning anaesthetic intervention. The absence of sensory input as a consequence of old spinal injury does not preclude an autonomic response to surgical stimulus, so anaesthesia is still necessary to facilitate surgery. A depressed sympathetic nervous drive below the level of spinal injury may permit an overriding parasympathetic nervous output. This renders the patient's cardiovascular system particularly vulnerable to effects of anaesthetic agents and airway manipulation. Labile heart rate and blood pressure, arrhythmias and cardiac arrest are possible results.

Often these patients present repeatedly, and have prolonged frequent hospital admissions. Care must be taken to prevent and detect colonisation and infection with multi-drug resistant organisms.

More specialist anaesthetic input into the long-term management of these patients may take the form of their pain management (Table 2). Pain and associated issues at this stage are often complex with far-reaching consequences and require a multi-modal approach.

Figure 2

Table 2 Pain Management Anaesthetic Interventions in the Long-term Management of Spinal Injury

- Intra-discal Electrothermal Therapy
- Intravenous Infusion : ketamine/ opioids/ colchicine, intrathecal baclofen/ opioids
- Injection into Joints or Trigger points: steroid/ hyaluronate/local anaesthetics/ botulinum toxin
- Epidural opioids/ steroids/ clonidine
- Peripheral Nerve Blocking procedures
- Neuroablation: glycerol/ radiofrequency ablation of dorsal root ganglia
- Neuromodulation: deep brain stimulation/ spinal cord stimulation

OPTIONS FOR AIRWAY MANAGEMENT AND ANAESTHETIC AGENTS

AIRWAY MANAGEMENT

The urgency of airway intervention is the most important factor in planning airway management for patients with potential cervical spine injuries. Other considerations include the assessment of the risk of cord injury with head and neck movement, the airway anatomy, the patient's degree of cooperation, and the anaesthetist's expertise.

The goal of the anaesthetist is to secure the airway without causing anatomical or physiological damage to the spinal cord. The considerations are valid for both complete and incomplete lesions, because manipulations can aggravate even complete lesions resulting in ascending deterioration.

Various techniques have been adopted for protection and maintenance of the airway. Current clinical data does not show any particular technique to be superior for tracheal intubation of patients with cervical spine injury. The emphasis for airway management is on operator expertise and managing each patient on a case specific basis.

Methods of immobilization that splint both head and torso to a rigid board (short board technique) are superior to collars in reducing movements in all planes[38]. Both hard and soft collars do not prevent movement of cervical spine during chin lift, jaw thrust and intubation. Routine use of spinal immobilization has been challenged especially in those with a low risk of cervical spine injury [39]

Spinal immobilization is not a risk free procedure and rapid exclusion of ASI clinically and/or radiologically must be made a priority. Complications include cutaneous ulceration, [40] raised ICP, [41 42] difficult airway management, [43] difficult central line insertion,[44] oral hygiene and enteral nutrition.

Any airway manoeuvre undertaken in a patient with an unstable spine injury has the potential to do harm. The Advanced Trauma and Life Support guide suggests patients requiring immediate and/or urgent airway control should be anaesthetised using a rapid sequence induction followed by orotracheal intubation with cricoid pressure and manual in-line immobilization of the head and neck.

This technique of emergency airway management involves, ideally, four individuals – the first to pre-oxygenate and intubate, the second to apply cricoid pressure, the third to maintain manual in-line immobilization of the head and neck and the fourth to give intravenous drugs and assist. The patient lies supine with the head in neutral position; an assistant applies manual in-line immobilization, whereupon the front of a rigid collar can be removed safely; the collar can impede mouth opening, does not contribute significantly to neck stabilization during laryngoscopy, and will obstruct placement of a surgical airway, if required. Manual in-line immobilisation, also called manual in-line axial traction, is an active process of applying a varying force to counteract the movements generated by laryngoscopy in an attempt to stabilise the cervical spine. There has been concern about the application of cricoid pressure in unstable cervical spine injury, and the impact of manual in-line traction[45 46 47].

AIRWAY POSITION

The 'sniffing the morning air' position for standard tracheal intubation is unsuitable in its flexion of the lower cervical spine and extension of the occiput on the atlas. Chin lift and jaw thrust have the greatest effect on narrowing the space for the spinal cord in the cervical canal, and they appear to offer the same magnitude of movement to the actual oral intubating technique [48 49]. Jaw thrust manoeuvres have been considered safe with the use of a rigid collar, however cadaveric studies have shown that they may cause distraction of as much as 5 mm with C5/6 instability[44 50].

Bag-Valve-Mask ventilation produces a significant degree of movement being more marked at C2-C5 level and comparable to direct Macintosh laryngoscopy [48 51]. Bag-valve-mask ventilation may be technically difficult with multiple facial injuries and can also lead to significant movement at the site of instability.

SUPRAGLOTTIC DEVICES

An oral (Guedel) or nasopharyngeal airway may be necessary to maintain a patent upper airway tract until a definitive airway is secured. Insertion of these devices produces minimal embarrassment of the cervical spine.

Standard Laryngeal mask exerts high pressure against the upper cervical vertebrae during insertion, inflation. Whilst in situ it seems that the continuous pressure of the cuff can produce posterior displacement of the upper cervical spine[52]

Intubating laryngeal mask (ILMA) is increasing in popularity. ILMA produces segmental movement of cervical spine despite in-line immobilization in the opposite direction of those observed during direct laryngoscopy. This movement is predominantly flexion above C5[52 53 54].

Orotracheal intubation has been widely accepted as the safest method to secure the airway in the trauma patient. Direct laryngoscopy disturbs the cervical spine by encouraging extension at the atlanto-occipital joint, so patients with unstable C1 or C2 injuries might be at highest risk during manipulation of the airway. Manual axial in-line stabilization reduces this movement by 60%. Manual in-line stabilization offers significantly less antero-posterior cervical vertebral displacement than cervical collar immobilisation during orotracheal intubation [55].

Blind nasal intubation may be successful in skilled hands, however it may require multiple attempts which increase the risk of bleeding, and then limit or compromise other airway management options. The process is often accomplished in non-trauma patients by rotating or flexing the neck to align the tube correctly in the spontaneously breathing patient by listening for movement of air at the end of the tracheal tube. It is therefore not a preferred method of airway management in the patient with acute spinal injury.

Flexible fiberoptic endoscopy may ease potential difficult intubation in patients with cervical spinal injury. This technique does not depend on atlanto-occipital extension and the head and the neck stabilizing devices can be left in place. However, there is no experimental evidence demonstrating that this method minimizes cervical spine movement. No statistical difference has been demonstrated in the outcome of unstable cervical spine patients anaesthetised by awake fiberoptic over asleep fiberoptic techniques [56]. If conditions permit, it has been suggested that awake nasal fiberoptic intubation should be the first choice, followed by asleep nasal or oral fiberoptic intubation [57 58].

Indirect video laryngoscopy offers an alternative to conventional direct laryngoscopy. The Glidescope and Airtraq devices are the more popular of several available. Limited evidence is available in the spinal injury population. There is some evidence to suggest that where the cervical spine has been immobilised, the Airtraq performed better than direct laryngoscopy, whilst the Glidescope showed no significant difference [59]. The Airtraq also appears to show reduced cervical spine motion during intubation than direct laryngoscopy [60]. Studies comparing the Glidescope to direct laryngoscopy yield conflicting results [61 62]. The total intubation time with the Glidescope is around thirty seconds [63]. A technique employing preoxygenation may render this an acceptable delay.

Lightwand intubation does not reduce significantly neck motion during intubation and it proved not to be superior to standard Macintosh laryngoscopy [64]

FAILED INTUBATION: ALTERNATIVE TECHNIQUES

There is always potential for failed intubation. It is important to recognize the problem and prioritise oxygenation while an alternative method of securing the airway is instituted. Senior help and surgical expertise need to be available at an early stage for the management of the potential difficult airway.

The Difficult Airway Society has published a suggested guideline for managing the failed intubation [65]. In addition to the use of the above airway management techniques, a LMA may be used to guide a size six tracheal tube either blindly or fiberoptically. The ILMA and indirect video laryngoscopes may feature in this scenario if the operator is familiar with these airway devices. The need for a surgical airway should be recognised and performed without delay to reduce the risk of irreversible ischaemic-hypoxic damage.

ANAESTHETIC AGENTS

The ideal anaesthetic agent does not exist, and once again it is down to the operator experience and patient's clinical condition on arrival to the emergency department and/or theatre (Table 3).

Figure 3

Table 3 Comparison of Anaesthetic Induction Agents for the Patient with Acute Spinal Cord Injury

Anaesthetic Agent	Advantages	Disadvantages
Etomidate	Minimal cardiovascular depression	Potential adrenal/ immunological suppression
Thiopentone	User familiarity	Hypnotic dose associated with significant cardiovascular depression
Propofol	User familiarity Careful use in conjunction with opioids and vasoconstrictors may negate hypotensive effect	Potential hypotension
Ketamine	Maintains cardiovascular stability	Raises intracranial pressure - patients at risk of head injury in this population.

The volatile anaesthetic agents are all suitable for use in spinal injury patients provided there is no ongoing measurement of motor evoked potentials as these are suppressed.

Special mention must be made of avoidance of the use of suxamethonium from day 3 for up to 2 years after spinal cord injury. There is overexpression of cholinergic receptors around denervated muscle mass, and the depolarisation initiated by suxamethonium may cause a rapid rise in serum potassium and ventricular arrhythmia or cardiac arrest.

CONCLUSION

Acute spinal injury is commonly seen in young male population and it carries a high morbidity and financial cost to society.

These patients present multiple anaesthetic considerations at various times in their emergent, surgical and intensive care management (Table 1).

The anaesthetist must recognise a potentially difficult airway, and minimize secondary damage by acting promptly in a familiar and safe manner. Tracheal intubation remains the gold standard for securing the airway. However, the safest method of achieving successful tracheal intubation remains debatable. The decision rests on operator recognition of the potential risks with choice of technique.

In view of limited evidence, there is no prescriptive anaesthetic technique to manage this group of vulnerable patients. Consequently, experience and attention to the multiple parameters that impact on outcome is vital, to give these patients the best chance of recovery of neurological function.

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