Airway Management in Neuroanesthesia

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Key Points

1. Airway management in neurosurgical population demands consideration of intracranial dynamics.
2. Major problems in airway management can significantly alter neurological outcomes.
3. Even when airway is not difficult, certain neurological conditions demand special airway management strategies.
4. Airway management in abnormal positions is common in neurosurgical population.
5. Most common non-supine positions for securing the airway are lateral and prone.
6. Knowledge about options and skills in execution are essential for successful outcome.
7. Apart from direct laryngoscope, supraglottic airway devises, fibreoptic-scope and videolaryngoscope are useful tools for securing the airway in non-supine positions.
8. When airway management in abnormal position is unsuccessful, airway should be secured by turning the patient supine.

1 Airway Management in Neurosurgical Patients

1.1 Introduction

Airway management in neurosurgical patients can be a formidable exercise. It impacts intracranial homeostasis [1] and hence, neurological outcome. Expansion of neurosurgical practice has enhanced airway challenges in day-to-day practice. Thousands of neurosurgeries are performed annually in India for traumatic brain injury (TBI) with or without associated cervical spine injury (CSI) and maxillo-facial trauma [2]. These patients, who require emergent airway management, present with unique challenges. Similarly, elective neurosurgical conditions such as acromegaly and paediatric neuropathologies (hydrocephalus, meningomyelocele, encephalocele, craniosynostosis or cranio-facial abnormalities), and certain procedures such as stereotactic surgeries and awake craniotomies require careful planning and deft airway management. This chapter reviews the spectrum of airway issues confronted by neuro-anaesthesiologists and discusses management approach to common airway problems in neurosurgical population.

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Contents: Airway and intracranial dynamics, other airway issues, extubation in neurosurgical patients (general aspects), airway assessment, airway in craniotomy, traumatic brain injuries, acute and chronic spinal cord injuries, paediatric neuroanaesthesia, airway in abnormal positions.

1.2 Airway Management and Intracranial Dynamics

Airway management in neurosurgical population is different compared to non-neurosurgical patients. Patients with intracranial pathologies often present with elevated intracranial pressure (ICP). Airway interventions without due considerations in these patients can lead to exacerbation of raised ICP and consequently, compromise cerebral perfusion and oxygenation. Difficult mask ventilation and prolonged time to secure the airway can cause hypoxemia and hypercarbia [3]. The use of standard induction dose of anaesthesia for intubation in patients with raised ICP causes hypotension and compromises cerebral perfusion [4]. Conversely, inadequate anaesthesia and analgesia during noxious stimulation of laryngoscopy and intubation activates autonomic system, increases heart rate and blood pressure [5], and can exacerbate ICP. The systemic changes also affect other aspects of cerebral physiology such as cerebral blood flow (CBF) and cerebral blood volume (CBV). These effects are pronounced in patients with low intracranial compliance such as those with a space occupying lesion, intracranial bleed from a vascular lesion or TBI [6].

Ruptured intracranial aneurysms are susceptible for re-bleeding during intubation which can lead acute increase in ICP and poor outcomes [7]. Occasionally, pseudo-aneurysm of the internal carotid artery can present as pulsatile oral mass. The twin challenges during intubation are to prevent direct injury to the vascular mass and alleviate hemodynamic stress. Combined techniques, McCoy laryngoscopy, and fibreoptic intubation (FOI) may be considered in such situation [8].

Judicious selection of anaesthetic agents and careful titration of their doses, administration of adjuvants such as preservative-free lignocaine, and liberal use of potent opioids which minimally interfere with intracranial dynamics and yet ablate cardiovascular response to intubation are essential to avoid significant alterations in systemic and cerebral physiology in neurosurgical patients.

1.3 Other Airway Issues in Neurosurgical Patients

The head is usually fixed using Mayfield clamp or stereotactic frame for cranial surgeries. This can pose problems if airway management is needed during surgery [9, 10]. Similarly, patients with acromegaly, CSI or post-craniotomy pseudo-ankylosis of temporo-mandibular joint [11] can present challenges during airway management.

1.4 Airway Management of a Neurosurgical Patient During Extubation

Swift and smooth awakening should be the hallmark of recovery from anaesthesia after neurosurgery. Significant elevation in the haemodynamic parameters during extubation can lead to brain oedema, haemorrhage, delayed awakening, additional investigations including brain imaging, redo-surgeries, and poor neurological outcomes [12]. Similar to that done during intubation, ablation of cardiovascular responses is needed at extubation. This can be achieved with the use of preservative-free lignocaine, small doses of short-acting opioids, infusion of low-dose dexmedetomidine, and use of sympatholytic drugs such as esmolol and labetalol [13, 14]. Alternatively, deep extubation can minimize hemodynamic activation during extubation. The advantages and disadvantages of awake and deep extubation are listed in Table 32.1. However, complete reversal of neuromuscular blockade must be ensured to prevent adverse respiratory events such as desaturation

Table 32.1 Awake versus deep extubation in neurosurgery

Awake extubation	Deep extubation
Advantages • Immediate neurological assessment and prompt action possible • Less likelihood of airway complications such as obstruction, hypercarbia and hypoxia • Preferable in difficult airway	Advantages • Smooth, pain free awakening • No coughing or haemodynamic activation • No significant changes in intracranial dynamics • Less complications such as laryngo- or bronchospasm
Disadvantages • Haemodynamic activation • Increase in intracranial pressure, and cerebral blood flow and volume • Potential for operative or remote haematoma and cerebral oedema, hyperperfusion syndrome, rebleed of unsecured aneurysm	Disadvantages • Inability to immediately assess neurological status • Potential for unwarranted imaging and other investigations, if regaining of consciousness is delayed after extubation • Potential for pulmonary aspiration, airway obstruction, hypercarbia and hypoxia and hence, reintubation • Not suitable for difficult airway

and hypoxemia, reduced minute ventilation and hypercarbia, and poor scores on motor system examination. Airway reflexes should return sufficiently to avoid potential pulmonary aspiration especially in patients with decreased consciousness. Apart from normal airway reflexes and sensorium, recovery of swallowing is also needed for successful extubation in some neurosurgical patients [15].

Extreme neck flexion is often used to facilitate neurosurgical exposure in prone or lateral position. This can result in macroglossia, oro-facial swelling, and airway oedema after prolonged surgery and lead to post-extubation airway obstruction, and difficult mask ventilation and intubation, if airway management is needed [16]. Similarly, patients undergoing trans-nasal endoscopic neurosurgery are at increased risk of contamination of the airway with blood from the surgical field. This can result in broncho- and laryngospasm, desaturation, and need for reintubation [17]. These issues should be borne in mind during extubation in neurosurgical patients.

Adverse airway events are not uncommon after neurosurgery and occasionally may require reintubation. Neurological deterioration, respiratory distress, unmanageable respiratory secretion, and seizures are the most common causes for reintubation after planned extubation in neurosurgical patients [18]. Where possible, such a scenario should be avoided by prudent planning of extubation and vigilant monitoring. Careful patient selection for on-table extubation, ensuring return of consciousness and airway reflexes, and anti-seizure prophylaxis can minimize reintubation after extubation in neurosurgical patients.

1.5 Strategies of Airway Assessment and Management in the Neurosurgical Patient

Sound knowledge about implications of airway management, appropriate evaluation, anticipation, and preparedness for a potentially difficult airway and strategy for uneventful extubation are crucial for successful airway management in neurosurgical patients.

A complete airway assessment may be difficult in a neurosurgical patient with sub-normal consciousness. Similarly, Mallampati grade (MG) assessment and its modified version which are performed in upright position and assessments such as thyro-mental distance which require cervical spine movement are not possible in patients with CSI. A higher MG is observed when the assessment is performed in supine as compared to the sitting position [19]. The modified MG assessment in supine position has better predictive value for difficult intubation than sitting position in neurosurgical patients [20]. Airway neurofibroma is not uncommon in patients with intracranial and spinal neurofi-

broma. Assessment of airway images may help in identifying them and planning airway management [21].

All neurosurgical patients should undergo airway evaluation irrespective of anaesthesia technique- local or monitored anaesthesia care (MAC), as conversion to general anaesthesia (GA) or resuscitation may be required on an emergency basis.

Basic principles of preparation for airway management

- Thorough preoperative airway assessment
- Presence of experienced anaesthesiologist and efficient technical or nursing help
- Availability of appropriate equipment including Ambu bag, at least two different size masks, laryngoscope blades and tubes, and working suction apparatus
- Availability of functioning monitors with appropriate alarm settings
- Prevention of pulmonary aspiration and airway obstruction in those with decreased consciousness
- Pre-oxygenation with 100% oxygen
- Availability of difficult airway cart with advanced airway gadgets

1.6 Airway Management in Patients Undergoing Craniotomy

1.6.1 Airway Evaluation

Detailed history, physical examination, and features of compromised intracranial compliance should be obtained to assess intracranial status. Preoperative cranial computed tomography (CT) or magnetic resonance imaging (MRI) scans provide relevant information about space occupying lesions, midline shift, and cerebral oedema which are indicators of poor cerebral compliance [22]. Airway management in these patients should avoid undue increases in ICP, CBF, or CBV. Airway evaluation may be impossible in obtunded patients and may be inadequate in bedbound patients [23]. In these patients, ultrasonography can be used for airway assessment [24]. In other patients, standard airway assessment should be performed.

1.6.2 Drugs During Airway Management

Premedication before anaesthetic induction for airway management should be avoided in obtunded patients. Intravenous midazolam 0.02 mg/kg may be considered in anxious patients [25]. The dose of intravenous anaesthetic agent should be titrated to loss of eyelash reflex or appropriate level on the depth of anaesthesia monitoring. Thiopentone is a time-tested induction agent, propofol does not irritate the airway and etomidate maintains hemodynamic stability. All these agents cause dose-dependent decrease in cerebral metabolic rate (CMRO2). The choice therefore depends on individual preference and patient status [26].

1.6.3 Airway Issues and Management During Awake Craniotomy (AC)

Airway evaluation in patients scheduled for AC is similar to other craniotomies. However, the presence of a difficult airway is a relative contraindication for AC [27]. Occasionally, AC may be performed for failed intubation [28] or to avoid airway intervention in presence of a large pulmonary bulla [29]. The most common anaesthetic technique for AC is MAC without airway intervention (Fig. 32.1). Here, scalp block is supplemented with intravenous dexmedetomidine or propofol infusion. Intraoperative airway obstruction is, however, more with propofol than dexmedetomidine [30].

Airway intervention during AC may be required in following circumstances: to protect airway from secretions, to rescue airway compromise from over-sedation, to reduce brain swelling from hypoventilation and desaturation, and to manage intraoperative seizure, uncooperative patient or procedural complication [30]. Ictal apnoea during awake surgical resection of a seizure focus [31] may require airway intervention if apnoea is prolonged.

There are few obstacles for emergency airway management during AC: presence of Mayfield head clamp restricting head and neck movement, need for maintaining sterile operating field, non-availability of space at head-end of the table, flexed or extended fixed head position and acute changes in neurological, and cardio-respiratory status requiring quick intervention. Supraglottic airway devices (SGADs) are most useful in such situations followed by videolaryngoscope. These should be immediately available for airway management. When asleep-awake-asleep technique is used for AC, removal and reinsertion of airway device can be challenging and can lead to adverse airway events [32].

Fig. 32.1 Awake craniotomy under monitored anaesthesia care without airway intervention

1.6.4 Intubation Strategies for Craniotomy

Figure 32.2 informs potential airway issues and strategies for airway management in patients undergoing craniotomies.

1.6.5 Peri-operative Airway Complications During Neurosurgery

Kinking of endotracheal tube (ETT) is mostly seen at the angle of the mouth [33], or from softening due to oral temperature and extreme neck flexion [34], external compression of the soft tip of flexometallic ETT from trans-thoracic echocardiography probe [35] or surgical retractor [36]. Mucus plug from dried secretions after prolonged surgery can occlude lumen of the ETT [37]. Broncho- or laryngospasm can also occur during neurosurgery. Such obstructions can result in elevated airway pressure, inadequate delivery of oxygen and removal of carbon dioxide, and brain swelling. The cause should be identified

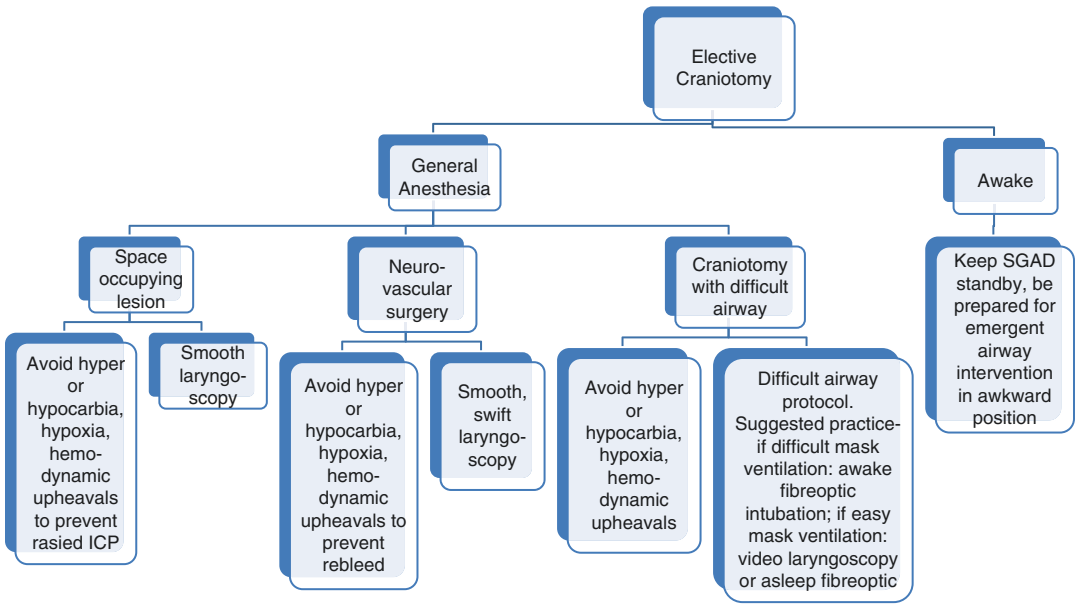

Fig. 32.2 Strategies for airway management for elective craniotomy

and rectified promptly. The causes can be differentiated by auscultation of lung fields, manual ventilation, physical checking, and tracheal suctioning. Occasionally, high airway pressure and unilaterally absent lung sounds may be due to midline shift from pulmonary tuberculosis and fibrosis rather than endobronchial intubation. Correct ETT position confirmation may require fibreoptic or fluoroscopic assessment [38].

Inadequate or non-delivery of oxygenation and ventilation during neurosurgery could be from ETT disconnection from the breathing circuit, ETT cuff leak, accidental extubation, and ventilator failure. The cause should be identified and promptly corrected by inspecting under the drapes for disconnection and reconnecting ETT, cuff inflation, or manual bag ventilation. If ETT is partly displaced, it should be repositioned. If this fails, airway may be re-secured using intubating laryngeal mask airway (ILMA), videolaryngoscope or FOI. Fixed head and sterile surgical field may impede access to the airway; covering surgical field with sterile drape and releasing head clamp facilitates quick airway management.

Dental injuries during difficult airway management [39] and bite injuries to the lips, tongue, and ETT during intraoperative neuromonitoring [40] are other airway complications during neurosurgery. Postoperative airway obstruction is possible from airway and tongue oedema after prolonged surgery with extreme neck flexion [41]. Table 32.2 summarizes common airway complications, causes, manifestations, and possible solutions during neurosurgery.

Table 32.2 Potential airway complications, their likely causes, manifestations and possible solutions during anesthesia for neurosurgery

Potential complications	Likely cause	Manifestations	Possible solutions
Postoperative airway obstruction [41]	Airway and tongue oedema from prolonged surgery and extreme flexion of the neck	Stridor, labored breathing, desaturation	Careful positioning, Cuff deflation and assessment before extubation, delayed extubation
Accidental disconnection	Drag of the breathing circuit, movement of head & neck	Loss of minute ventilation, low airway pressure, desaturation	Careful respiratory monitoring, secure connections of the breathing system
Accidental extubation	Secretions especially in prone	Loss of minute ventilation, low airway pressure, desaturation	Anti-sialogouge prophylaxis, careful securing of the tube
Kinking of the tube (External obstruction) [33–36]	Over-bending and softening of tube from prolonged exposure to oral temperature and neck flexion; kinking of soft tip of tube by trans-esophageal echo probe Kinking of tip of tube with retractor during neck surgery	High airway pressure, Inability to ventilate, desaturation, full brain	Flexometallic tube, Two-finger gap between chin and sternum during positioning Avoid probe manipulation, consider PVC tube Push tube beyond retractor or use PVC tube
Tube blockage (internal obstruction) [37]	Mucus plug and dried secretions	High airway pressure, Inadequate ventilation, inability to pass suction catheter	Suctioning with good negative pressure, Manual ventilation, Reintubation with new tube
Bite injuries of tongue, lips, tube [40] Dental injuries [39]	Motor evoked potential monitoring Loose teeth, difficult intubation	Loss of tidal volume, bleeding and swelling Bleeding, missing teeth	Adequate anesthetic depth, bite block, periodic inspection, neuro-muscular function monitoring Care during intubation, retrieval

1.6.6 Extubation Strategies for Craniotomy

Figure 32.3 informs about issues, precautions, and approaches to extubation in patients undergoing craniotomy with routine and difficult airway.

1.7 Airway Management in Patients with Traumatic Brain Injury

1.7.1 Indications for Artificial Airway

The most common indications for airway management in patients with TBI are (1) Glasgow coma scale (GCS) score <9, (2) Potential for pulmonary aspiration of blood, secretions, and gastric contents, and (3) Need for normoxia, hyperventilation or pharmacological coma to manage raised ICP. Patients with TBI are likely to have associated maxilla-facial injuries and CSI which complicate airway management in these patients [42].

1.7.2 Concerns During Airway Management

- Raised ICP—potential for aggravation with airway intervention
- Full stomach—risk of pulmonary aspiration
- Cricoid pressure during rapid sequence intubation (RSI)—complicates glottic view
- Airway contamination with blood, secretions, foreign materials—poor airway vision
- Unstable cervical spine—need for stabilization to prevent neurological worsening
- Altered consciousness—airway assessment not possible
- Facio-maxillary injury—mask ventilation difficult
- Skull base fracture—potential for pneumocephalus, cerebrospinal fluid (CSF) leak and infection
- Prolonged intubation time—possibility of hypoxia, hypercarbia and further rise in ICP
- Poor GCS—usual induction dose leads to hypotension and reduced cerebral perfusion
- Uncooperative/agitated patient—larger anaesthetic dose causes hemodynamic collapse.

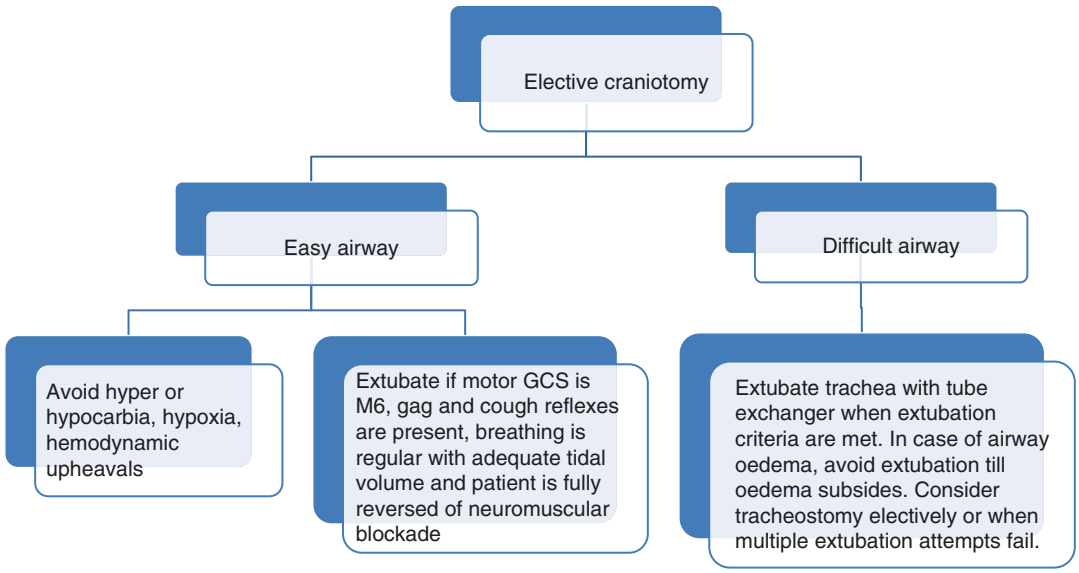

Fig. 32.3 Extubation strategies after elective craniotomy

1.7.3 Considerations During Airway Management

There is no safe and best airway management technique in TBI. Airway management depends on urgency of securing the airway, experience, and skill of the performer, and availability of resources in the emergency situation. An oral route for tracheal intubation is preferred especially if breach in skull base is suspected. Videolaryngoscope, if available, should be preferred over conventional laryngoscopy due to its advantages. Major fluctuations in haemodynamics should be avoided as it affects intracranial physiology [43].

Preoperative brain CT provides information about hematomas, oedema, midline shift and thus, extent of cerebral compliance. Improper airway management can be harmful if intracranial compliance is poor. Radiological imaging may also provide airway information helping plan airway management [44]. Mask ventilation can predispose to infection and pneumocephalus in TBI patients with skull fractures, maxillo-facial injuries, and CSF rhinorrhoea or otorrhea [45]. Occasionally, TBI may result in epistaxis from carotico-cavernous fistula. Aspiration of blood into the airway and desaturation requires emergency intubation. [46]

1.7.4 Suggested Airway Management (Modified Rapid Sequence Intubation)

- Pre-oxygenation with 100% oxygen
- Monitoring of cardio-respiratory function (a minimum of electrocardiogram, pulse oximetry, and non-invasive blood pressure)
- Dose of thiopentone, propofol or etomidate titrated to haemodynamics and consciousness.
- Liberal dose of opioid such as fentanyl.
- Rapidly acting neuromuscular blocking agent such as succinylcholine or rocuronium.
- Preservative-free lignocaine to ablate nociceptive response to laryngoscopy and intubation.
- Cricoid pressure ± BURP manoeuvre to quickly and safely secure the airway.
- Manual in-line stabilization (MILS) if suspected or confirmed CSI (Fig. 32.4).
- Swift and smooth orotracheal intubation by a skilled performer.

Fig. 32.4 Manual inline stabilisation technique

1.7.5 Extubation Strategies

It is important to assess readiness for extubation in patients with TBI. This can be determined by preoperative and postoperative neurological status, imaging findings, intraoperative course, and cardio-respiratory status. Other factors that contribute to extubation success are younger age, presence of cough, and negative fluid balance [47]. Vigilant postoperative monitoring should be performed in either case of extubation or retained airway as clinical condition can rapidly change in TBI patients.

1.8 Airway Management in Patients with Cervical Spine Injury

1.8.1 Concerns and Considerations

The major concern in patients with CSI is potential for worsening of neurological status during airway management and hence, assessment of neurological function after intubation is desirable [48]. Also, CSI is often associated with autonomic system dysfunction which can manifest as exaggerated hemodynamic changes during airway management [49]. Airway management

strategy should consider emergency or elective nature of airway intervention, operator expertise, cardio-respiratory, and neurological status of the patient and resources available. Patients with CSI require airway management for medical or surgical treatment of CSI, management of associated TBI or for other surgeries.

1.8.2 Evaluation of CSI and Airway

Assessment of CSI is important to plan airway management [50]. CSI is unlikely if (1) patient is alert and oriented with GCS of 15, (2) drug or intoxication that may alter the sensorium is absent, (3) midline pain or tenderness is absent, (4) full range of active cervical spine movement is possible, and (5) if neurological deficit attributable to CSI is absent. Plain radiography, CT, MRI, and dynamic fluoroscopy of cervical spine provide information about cord compression and anatomical status of the spinal column. The imaging modality also provides clue to potential airway difficulty. Range of cervical spine motion assessment may not be possible and MG has to be assessed in supine position.

1.8.3 Intubation Strategies

Instability is common after traumatic CSI. Additionally, cervical spine movement occurs during airway interventions. The goal of airway management in CSI is to prevent cervical spine movement during intubation and consequently, new neurological deficits. Hence, MILS, hard cervical collar, and head traction are used to immobilize cervical spine. These techniques can, however, complicate airway management. Removing anterior portion of cervical collar before intubation facilitates mouth opening and is suggested [51]. Though MILS makes glottic view difficult, it is suggested during direct laryngoscopy and intubation and minimizes neurological sequalae [52]. The suggested intubation strategies for CSI is outlined in Fig. 32.5.

There is lack of guidelines for airway management in CSI. Most anaesthesiologists, however,

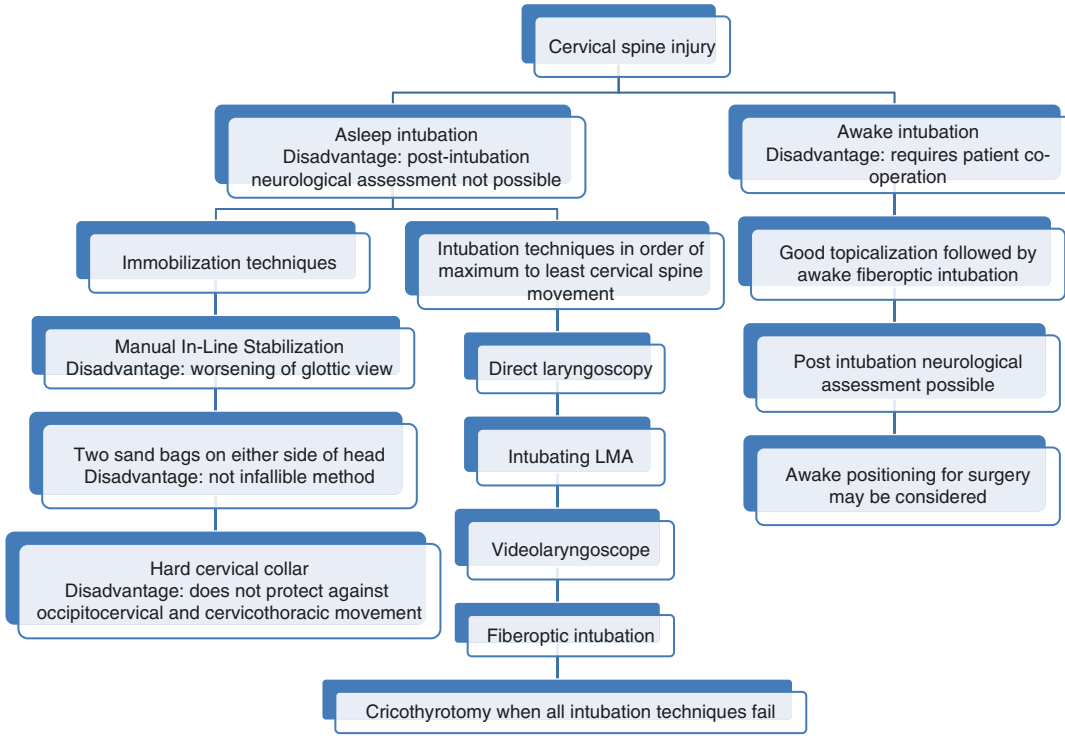

Fig. 32.5 Intubation strategies for cervical spine injury

prefer FOI for elective intubation in patients with CSI, while direct laryngoscopy with MILS is opted for emergency intubation [53]. Awake intubation with videolaryngoscope provides similar intubation conditions to awake FOI in CSI [54]. Likewise, awake ILMA assisted intubation results in similar degree of cervical spine movement and intubation success as compared to awake FOI [55]. Glidescope does not cause less cervical movement as compared to direct laryngoscopy but improves glottic view and success of intubation [56]. Nasotracheal intubation, light wand, retrograde intubation, and Bullard laryngoscope are other techniques described for securing the airway in CSI [52].

1.8.4 Extubation Strategies

Extubation in patients with CSI should be well planned. About 80% of patients can be successfully extubated. However, patients with complete CSI fail extubation and require tracheostomy [57]. Other factors that can affect extubation include the number of segments involved, older age, intraoperative complications, and significant respiratory system involvement. In high-risk patients, delayed extubation is recommended. Reintubation after cervical fixation is difficult as neck manoeuvrability is lost. Airway may be re-secured using SGAD, videolaryngoscope or FOI.

1.9 Airway Management in Patients with Chronic Cervical Spine Disease

Patients with chronic cervical spine disease may present for decompressive surgery for treatment of myelopathy or for non-spine surgery.

1.9.1 Concerns During Airway Management

1. Traditional bedside tests to predict difficult airway are not reliable as examining the range of spine motion may not be warranted. Size of epiglottis, thickness of tongue, and impaired mandibular protrusion are better predictors of difficult intubation.
2. Pre-vertebral collection from cervical spine tuberculosis can compromise the airway and present challenge during intubation. Awake FOI with a smaller size tube is suggested [58].
3. Patients with ankylosing spondylitis (AS) can present with fixed cervical flexion deformity and intubation difficulty [59].
4. Rheumatoid arthritis (RA) may be associated with temporo-mandibular arthritis, crico-arytenoid arthritis, and atlanto-axial instability complicating airway management [60]. These patients may develop post-extubation stridor and airway obstruction though this is less likely with FOI than after direct laryngoscopy [61].
5. It is important to differentiate short stature from dwarfism *versus* severe scoliosis during airway management to avoid endobronchial intubation or accidental extubation during surgery. Tube fixation depends on orotracheal distance which is normal in scoliosis while it is reduced in dwarfism [62].

1.9.2 Airway Management Strategy

1. Avoid further damage to spinal cord and worsening of symptoms of myelopathy by minimizing cervical spine movement
2. Intubation strategies of acute CSI may be followed. Awake intubation and self-positioning helps to always monitor neurological status [63].

1.10 Airway Management in Patients with Acromegaly

Acromegaly is caused by excessive growth hormone production from the anterior pituitary secondary to pituitary tumour. Usually, these patients present for trans-sphenoidal or trans-cranial tumour decompression. Airway problems mainly arise from overgrowth of bony and soft tissues, and multisystem involvement.

1.10.1 Airway Concerns

The incidence of difficult airway is higher in acromegalic patients and is predicted by higher MG [64]. Macroglossia, large mandible, exces-

Fig. 32.6 Macroglossia in a patient with acromegaly

sive soft tissue in oro-pharynx (Fig. 32.6) impaired cervical spine mobility, and enlarged epiglottis contribute to difficult mask ventilation and intubation [65].

Recurrent laryngeal nerve palsy, narrow glottic, and subglottic space predisposes these patients to postoperative stridor. Insertion of nasal airway during emergence is not possible after trans-nasal surgery. Even after trans-cranial surgery, a smaller size should be considered as these patients have enlargement of nasal turbinates.

Other concerns that can complicate airway management are obstructive sleep apnoea (OSA), systemic and pulmonary hypertension, diastolic cardiac dysfunction, coronary artery disease, cardiomyopathy, arrhythmias, raised ICP secondary to pituitary tumour, and hyperglycaemia associated changes in autonomic function [66].

1.10.2 Intubation Strategies

Difficult intubation trolley and experienced anaesthesiologist should be available for intubation. When asleep technique is planned, three persons may be needed—one to maintain mask seal, second to provide vertical counter pressure, and third to provide bag ventilation. Appropriate size oro-pharyngeal airway, suction apparatus, and smaller size ETT should be available. Airway trauma is a likely during intubation attempts. Passing of ETT beyond glottis may be challenging due to hypertrophied arytenoids. Smaller size ETT or rotation of ETT by 90° helps in this situation. Awake FOI is the preferred technique in patients with acromegaly. Alternatively, airway can be secured using SGAD, videolaryngoscope, or gum elastic bougie [66].

1.10.3 Extubation Prerequisites

Following trans-nasal pituitary surgery, nasal cavity is packed. Hence, preoperative patient education about mouth breathing after surgery is essential. Removal of throat pack after suctioning of blood and airway secretions should be performed. Smooth emergence without coughing is essential after trans-nasal surgery to avoid CSF leak, dislodgement of fat graft and nasal pack, and avoid raised ICP. Prior to extubation, patient must be fully awake, hemodynamically stable, have complete neuromuscular recovery and exhibit adequate respiratory drive and effort [67].

1.10.4 Extubation Strategies

Awake versus deep extubation strategy is debatable. Awake extubation if stormy, can result in hemodynamic activation, ICP increase, and CSF leak but reduces postoperative adverse respiratory events. Deep extubation while mitigating hemodynamic instability, coughing, and bucking can lead to airway obstruction and desaturation requiring reintubation. Presence of OSA, large tongue, and increased upper airway adipose tissue predispose to postoperative airway obstruction. However, continuous positive pressure ventilation and naso-pharyngeal airway are contraindicated after trans-nasal pituitary surgery [67]. Therefore, awake extubation should be considered in these patients.

1.11 Airway Management in Patients with Halo-frame or Stereotactic Frame

Halo-frame is a device used to provide external cervical immobilization in patients with unstable CSI. Halo-frame restricts cervical spine movement and limits access to the airway making intubation difficult. Hence, FOI or SGAD may be preferable [68]. Patients with traumatic CSI and halo-frame, who require emergent intubation,

have poor outcome. Early tracheostomy is desirable in patients with high injury severity score, and significant cardio-respiratory problems [69].

Stereotactic procedures are performed for biopsy, radiosurgery, and movement disorders. Cooperative adults allow stereotactic frame fixation with local anaesthesia with minimal or no sedation. Children and non-cooperative or obtunded adults may require GA or MAC with intravenous sedation. In obese patients or those who are susceptible for airway obstruction, airway should be secured prior to frame fixation. Challenges of securing airway with the stereotactic frame in situ include inability to achieve sniffing position and difficult access to airway from caudally directed cross-bar of the frame [70]. Such problem is not seen with cranially directed cross-bar (Fig. 32.7) or frameless stereotaxic procedures. However, patients with Cheyne–Stokes respiration from brainstem pathology undergoing stereotactic procedures can pose airway challenges, necessitating appropriate selection of sedative drugs [71]. Emergent airway management may be required during complications such as bleeding, air embolism, and seizures. SGADs and videolaryngoscope are preferable in patients with stereotactic frame [10]. Allen wrench should be available to dismantle the stereotactic frame.

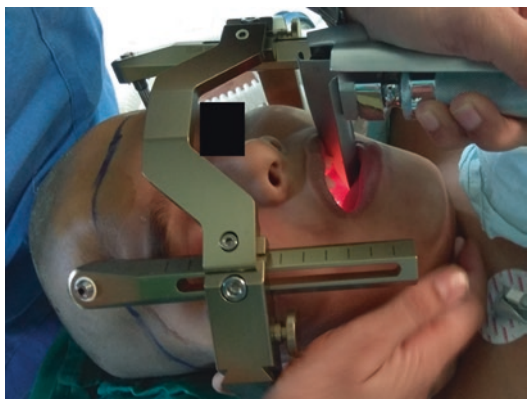

Fig. 32.7 Airway intervention in a patient with stereotactic frame in situ and cranially directed crossbar providing space for laryngoscope insertion

1.12 Airway Management in Paediatric Neurosurgery

1.12.1 Considerations

Paediatric neurosurgical patients may pose airway challenges both from issues inherent to paediatric airway and neurosurgical pathology. Airway intervention should be smooth and swift due to narrow neurophysiological and cardio-respiratory safety margin. Cerebral autoregulation range is narrow (20–60 mmHg) in newborn [72]. Hemodynamic changes during airway management may lead to either cerebral ischemia or intraventricular haemorrhage as brain receives significant proportion of cardiac output [73]. Children with large mass lesions and open fontanels have minimal clinical signs despite advanced cerebral pathology.

1.12.2 Airway Evaluation

Encephalocele, hydrocephalus, and craniosynostosis are commonly encountered paediatric neurosurgical pathologies which present with airway challenges. Evaluation of paediatric airway involves examination of the head and neck. Indicators of difficult airway include noisy breathing, snoring, breathing difficulty while feeding and recurrent respiratory tract infection [74]. Knowledge of various paediatric syndromes is essential for the management of difficult paediatric airway.

1.12.3 Airway Strategies

Awake FOI with sedation is desirable for anticipated difficult airway in cooperative older children. In others, GA with sevoflurane to an anaesthetic depth that allows intubation with any gadget while retaining spontaneous respiration may be preferable. Surgical airway should be considered when all other options fail.

1.12.4 Encephalocele

Encephalocele is a neural tube defect of the head, which usually occurs in occipital, frontal, or nasal regions. Patients with encephalocele may

be associated with other syndromes complicating the airway issues [75]. Anteriorly located encephalocele may interfere with mask ventilation and laryngoscopy (Fig. 32.8). Occipital encephalocele makes positioning difficult during intubation (Fig. 32.9). A doughnut may be used with the encephalocele lying in the eye of the doughnut. Airway can be secured by making an elevated platform of rolled-up blankets below the body and head supported on the table [76], or with the body on the table and head hanging from the edge of the table [77] or using additional manpower to lift the child to aid intubation [78]. Alternatively, or when these techniques fail, tracheal intubation should be considered in lateral position.

1.12.5 Hydrocephalus

In small children with hydrocephalus, airway management is complicated due to disproportionately large head (Fig. 32.10), raised ICP, and associated syndromes. The most commonly used technique is "stacking" or "ramping" where the body is elevated with support of pillow or blankets to align the oro-pharyngeal-laryngeal axis for intubation [79] and if necessary, head supported on sides by rolled towels or sand bags. Alternatively, child may be taken to the edge of the table with head supported by an assistant for intubation. Intubation with deep inhalational anaesthesia retaining spontaneous respiration is preferred. In adults, though head size is not an issue, the choice of airway is important. LMA, though preferable due to short duration ventriculoperitoneal shunt surgery and minimal hemodynamic activation in patients with raised ICP, can cause inadequate ventilation due to potential displacement during tunnelling or neck rotation [80].

Fig. 32.8 Anteriorly located encephalocoele

Fig. 32.9 Occipital encephalocoele

Fig. 32.10 Disproportionately large head with hydrocephalus

1.12.6 Cranio-facial Anomalies

Children presenting with craniosynostosis (Fig. 32.11) may have associated acro-cephalo-syndactyly disorders. Airway anomalies associated with Apert's syndrome [81] are small nasopharynx, hypoplastic maxilla, trismus related to temporalis muscle fibrosis and tracheal cartilage sleeve abnormalities predisposing to OSA. Airway anomalies associated with Crouzon's syndrome [82] include beaked nose, short upper lip, misaligned teeth, narrow, high or cleft palate, bifid uvula, hypoplastic maxilla, mandibular prognathism, and cervical fusion. Airway anomalies associated with Down's syndrome [83] are smaller mid face, macroglossia, narrow nasopharynx, larger tonsils and adenoids, short palate, laryngo-tracheomalacia, subglottic stenosis, ciliary hypomotility, and atlanto-axial instability. Children with Klippel-Trenaunay syndrome [84] may manifest with soft tissue hypertrophy of the airway necessitating careful evaluation and appropriate airway management. Patients with Smith-McCort dysplasia also present with several challenges which can complicate airway management [85].

Airway management in children with neurological disabilities at remote location can be further challenging. Retaining spontaneous respiration and preventing airway obstruction during sedation for MRI is important to prevent an emergent airway situation. Dexmedetomidine may be preferable to propofol in such situation as it fulfils both the criteria [86, 87].

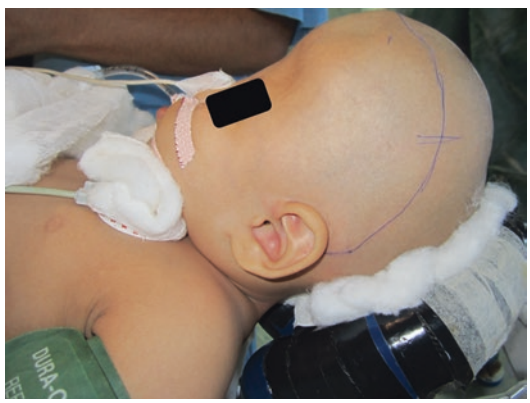

Fig. 32.11 Child with craniosynostosis

1.12.7 Intubation Strategies

Raised ICP, neuro-developmental issues, and associated syndromes are common in children with craniosynostosis. Preoperative sedation should be preferably avoided [88]. Anxiety may be reduced by parental presence during anaesthetic induction. Both mask ventilation and intubation may be challenging. Difficult airway cart should be available including preparation for surgical airway. Inhalational induction and direct laryngoscopy intubation is the most common technique. Muscle relaxant may be considered prior to tracheal intubation when mask ventilation is feasible. Alternate airway gadgets have also been successfully used to secure the airway.

1.12.8 Extubation Strategies

Factors that delay postoperative extubation are prolonged procedure in prone position with signs of upper airway oedema, marked fluid shifts, large volume transfusions, and preoperative OSA [88]. Extubation should be performed when the child is awake, has satisfactory breathing efforts, and is hemodynamically stable. Appropriate airway gadgets should be ready for emergent postoperative tracheal intubation.

2 Airway Management in Abnormal Positions During Neurosurgery

2.1 Introduction

In normal circumstances, airway is secured in supine position for neurosurgical patients. Airway management in non-supine position may be desirable in some conditions and may be essential in an emergency scenario. Hence, anaesthesiologists should have sound knowledge about various options of managing the airway in non-supine positions and acquire requisite skills to execute them. In this section, we will discuss issues and options of airway management in abnormal positions in the neurosurgical population.

2.2 Airway Management in the Lateral Position

Loss of airway during surgery in a laterally positioned patient can result in undesirable consequences unless airway is secured quickly and safely. Most anaesthesiologists, both due to the lack of need and practice, are less comfortable in securing the airway in this position. Securing the airway in the lateral position may be needed as a rescue technique in an emergency scenario or as an alternative method during elective airway management. The lateral position provides certain advantages over the supine position during airway management such as lesser airway collapse under anaesthesia [89], better range of neck movement, and lower risk of pulmonary aspiration of gastric contents [90]. Both right and left lateral position can be used depending on the preference of the anaesthesiologist. However, for the right-handed, right lateral position provides better manoeuvrability of the left-hand during laryngoscopy and intubation.

Apart from direct laryngoscopy, airway can also be secured in the lateral position using fibreoptic-scope [91] and ILMA [92]. Certain airway techniques have higher success when used for airway management in the lateral position. A randomized controlled trial (RCT) comparing airway management with ETT placement and LMA placement in left lateral position noted deterioration of laryngoscopy view, more airway failure, and longer time to secure the airway with intubation than with LMA. This suggests that LMA is superior to intubation in securing the airway in lateral position [93].

In neuroanaesthesia practice, airway management in the lateral position may be advantageous in children with occipital encephalocoele, meningomyelocele involving thoracic, lumbar, and sacral region (Fig. 32.12), and macrocephaly.

2.2.1 Encephalocoele

Issues during airway management in occipital encephalocoele are possibility of rupture of encephalocoele and safely securing a potentially difficult airway due to restricted neck movement from the encephalocoele [94]. Though difficult mask ventilation and intubation are common, most intubations can be successfully performed in lateral position with direct laryngoscopy [95]. Videolaryngoscope such as Airtraq offer great

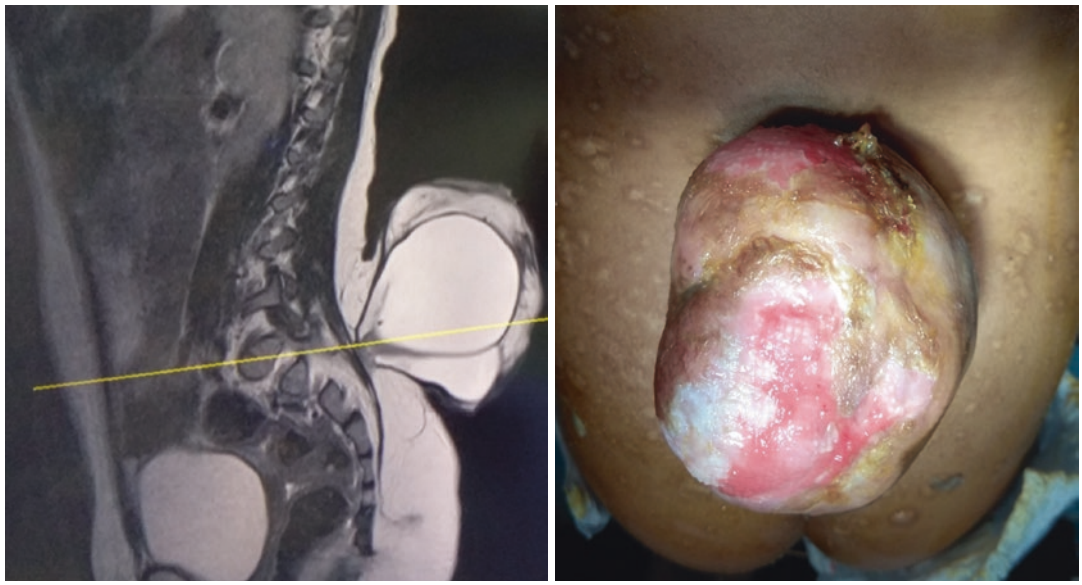

Fig. 32.12 Sacral meningo-myelocoele

success in intubation in lateral position, when conventional laryngoscopic intubation in supine position fails [96].

2.2.2 Meningomyelocele

Many anaesthesiologists prefer supine position for securing the airway in infants with meningomyelocele using a doughnut or a head ring placed below/around the swelling to protect it. This has disadvantages such as risk of rupture, infection, and neural damage. Intubation in lateral position is therefore preferred by others but is challenging. A RCT comparing supine with lateral position for intubation in 60 infants undergoing lumbo-sacral meningomyelocele repair observed that time for intubation and attempts for successful intubation were comparable with both positions [97].

2.2.3 Macrocephaly

The presence of a large head in a small child with hydrocephalus results in flexion of the neck and a large forehead obscures laryngoscopy view, making intubation difficult in supine position. Placing the child in lateral position facilitates alignment of the intubation axis and improves success in securing the airway [98].

2.3 Airway Management in Prone Position

Prone position is neither preferred nor warranted for elective intubation. Airway management in prone position is almost always an emergency when accidental extubation occurs during posterior fossa or spine neurosurgery. Prone intubation avoids turning the patient supine in the middle of surgery and minimizes risk of infection and delay. Occasionally, emergency airway management in prone position may also be necessary during spine or peripheral nerve surgeries performed under regional anaesthesia. Additionally, emergency airway management in prone position may be needed during adverse events such as kinking or biting of ETT or cuff damage causing loss of ventilation, as these events are more likely during surgery performed in prone position.

Concerns during airway management in prone position include difficult access to the airway, inability to view laryngeal inlet with laryngoscopy, presence of airway oedema necessitating use of a smaller ETT, inward or outward migration of ETT with flexion and extension, difficulty with pre-oxygenation, bag mask ventilation or placement of artificial airway, and limited mobility of head and neck especially in the presence of horse shoe or skull-pin fixator.

Accidental extubation in prone position, though rare, is quite challenging to manage. Turning the patient supine for securing the airway may not be always possible due to factors such as time, personnel, and sterility, necessitating airway management in prone position itself. LMA is the commonest rescue tool to emergently secure a lost airway [99]. The advantages of placing SGAD in prone position include (1) ease of insertion from anterior displacement of tongue providing space for SGAD, (2) better seal due to cephalic displacement of larynx, and (3) reduced risk of aspiration as gravity will drain airway secretions [100]. A study evaluated success of SGAD insertion by 40 anaesthesia residents in a manikin with its head placed on horseshoe to simulate prone position for cervical spine surgery. They observed that all SGADs were successfully inserted in prone position. However, I-gel was associated with the best insertion score and shortest insertion time compared to classic LMA and ProSeal LMA [101]. Experience and expertise play a major role in speedy and successful placement of airway device in prone position during emergency [102]. ILMA too has been successfully used to secure the airway in prone position in patients with impaled knife protruding out of lower back [103] and open wound over the back with fractured pelvis [104].

Videolaryngoscopes are also useful in securing the airway in prone position. Airtraq was successfully used for reintubation in prone position in a patient undergoing lumbar spine surgery when the tracheal cuff malfunction resulted in significant leak and difficulty with ventilation [105]. Similarly, awake fibreoptic intubation was successfully performed in prone position to secure the airway in a patient with a large knife

protruding from upper back [106]. Though direct laryngoscopy is the least preferred and most difficult technique in prone position, it has been used under GA to secure the airway in a patient with penetrating thoracic spine injury after failed FOI. Successful intubation was performed by anaesthesiologist sitting on the floor and bringing the head at the edge of the operating table [107].

2.4 Airway Management in Sitting Position

Sitting position is commonly used for neurosurgery especially for posterior fossa surgery. Emergent airway management may be needed during sitting craniotomy (Fig. 32.13) if inadequate oxygenation or ventilation occurs during surgery from any cause. The airway management in this position is complicated by limited access to the airway, flexed position of the neck, presence of Mayfield head clamp, surgical field obstructing head-end approach to the airway. Release of the head clamp to provide neutral or extended neck position and partial lowering of the backup table position can facilitate access to the airway. Airway can be secured using suitable techniques such as SGADs, FOI, or videolaryngoscope which have higher success than conventional laryngoscopy.

Fig. 32.13 Sitting position

3 Conclusions

Challenges of airway management in neurosurgical patients require competence in various modes of securing the airway. Anaesthesiologist should consider intracranial physiological requirements of a neurosurgical patient as well specific airway concerns for a successfully securing the airway. Airway management in abnormal positions is not unusual during neurosurgery. Anaesthesiologist should obtain adequate knowledge and appropriate skills in management of such situations to achieve good outcomes.

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