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Review article

Caring for the patients with cervical spine injuries: what have we learned?

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Abstract

Purpose: Anesthesiologists are often involved in the early management and resuscitation of patients who have sustained cervical spine injuries (CSIs). The most crucial step in managing a patient with suspected CSI is the prevention of further insult to the cervical spine (C-spine). In this review, important factors related to initial management, diagnosis, airway and anesthetic management of patients with CSI are presented.

Source: Medline search was performed to seek out the English-language literature using the following phrases and keywords: *spine trauma*; *cervical spine*; *airway management after CSI*.

Principal Findings: Cervical spine injury occurs in up to 3% to 6% of all patients with trauma. The initial management of a patient with potential spine injury requires a high degree of suspicion for CSI so that early stabilization of the spine can be used to prevent further neurological damage. Diagnostic radiology has a critical role to play; however, clinical evaluation is equally important in excluding CSI in a conscious and cooperative patient. Although in-line stabilization reduces the movement at C-spine, traction causes clinically significant distraction and should be avoided.

Conclusion: A high level of suspicion and anticipation are the major components of decision making and management in a patient with CSI. Endotracheal intubation using the Bullard laryngoscope may have some advantages over other techniques as it causes less head and C-spine extension than the conventional laryngoscope, and this results in a better view. However, the current opinion is that oral intubation using a Macintosh blade after intravenous induction of anesthesia and muscle relaxation along with inline stabilization is the safest and quickest way to achieve intubation in a patient with suspected CSI. In summation caution, close care and maintenance of spinal immobilization are more important factors in limiting the risk of secondary neurological injury than any particular technique.

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1. Introduction

Anesthesiologists are often involved in the early management and resuscitation of patients who have sustained cervical spine injuries (CSI). A critically important responsibility of the anesthesiologist is the airway management. When cervical spine (C-spine) stability is not in question, the airway is usually secured with direct laryngoscopy and oral endotracheal intubation while applying cricoid pressure after induction of general anesthesia. However, in trauma and emergency situations, there is a potential for CSI. Various methods to stabilize the spine are used to reduce C-spine movement during airway manipulation. In this review, important aspects of clinical and radiological diagnosis and airway management of patients with CSI will be presented.

2. Epidemiology

Cervical spine injury occurs in up to 3% to 6% of all patients with trauma [1-4]. It may also be present in as many as 10% of patients with significant head injury [5-7]. The critical nature of these injuries is underscored by the fact that nearly half of the approximately 14 000 patients who present to hospitals annually in North America with spine injuries died on the scene [8]. There are different causes of injury to the spinal column and spinal cord. The most frequent are motor vehicle accidents, which account for 45% of spinal injuries. Fall, sports, and acts of violence account for approximately 20%, 15%, and 15% of CSI, respectively. Suspicion of neurologically significant injuries should be especially high in patients with CSI after motor vehicle accidents and sports injuries, as 50% and 90% of these patients will become quadriplegic, respectively.

3. Initial management

The initial management of a patient with potential spine injury requires a high degree of suspicion for CSI so that early stabilization of the spine can be used to prevent further neurological damage. However, concomitant life-threatening injuries such as hemorrhage or airway compromise, which comprise up to 5% of spinal injuries, should be treated first. Nevertheless, stability of the C-spine need not be put at risk during resuscitation and treatment of these injuries. All patients with multiple traumatic injuries should be placed on a firm surface with full C-spine immobilization during initial resuscitation and treatment. Different methods may be used to immobilize C-spine. These include a variety of head immobilizers and cervical collars, but as yet, there is no consensus on the best method [9,10]. However, the most frequently used method is the combination of a hard cervical collar and a backboard [11].

A combination of a rigid cervical collar and supportive blocks on a backboard with straps is effective in limiting motion of the C-spine and are recommended. The long-standing practice of attempted C-spine immobilization using sandbags and tape alone is not recommended [12]. In pediatric population, the prehospital C-spine stabilization is best accomplished by using a rigid-type cervical collar in combination with supplemental devices such as Kendrick Extrication Device and half-spine board [13].

An ideal cervical collar should be light, easy to apply, and provide firm cervical immobilization. It should also provide a rapid access to the anterior neck for surgical access to the airway if needed. Appropriate positioning of the collar should be easy to accomplish because if the cervical collar is not correctly positioned, it may obstruct the airway by forcing the mandible posteriorly. Too tightly applied collar can also obstruct the circulation, which may cause a rise in intracranial pressure in the patient with head injury [14] or airway compromise in the presence of an expanding neck hematoma.

When used alone, even the best of the cervical collars did not provide acceptable immobilization allowing 17° flexion, 19° extension, 4° rotation, and 6° lateral motion. When combined with supplemental devices such as Kendrick Extrication Device and half-spine board, immobilization to 3° or less in any direction could be achieved [13]. Of the many cervical collars available, most allow considerable rotation and lateral bending of the neck in the absence of a spine board [15].

A long spine board or rescue board is used frequently in prehospital and transport settings. Once the patient is in the hospital, the board serves no purpose beyond that of a firm bed and should be removed as soon as possible. The spine board is extremely uncomfortable, and prolonged use can lead to skin damage. Controlled transfers within the hospital and operating room can be carried out with sliding boards or scoop methods, provided there are enough trained individuals to perform these maneuvers.

When deciding on the appropriate firm surface to use as a backboard, the relationship of the axial skeleton to the backboard must be considered. In adults, the head is relatively smaller in anteroposterior direction when compared with the body, and the C-spine may be in extension without some form of occipital padding. The opposite is true for children, who have relatively larger heads and whose C-spines lie in flexion in supine position. Some backboards have recessed pits for the heads of children.

Finally, pharmacologic neuroprotection should be considered early in the course of treatment. The role of methylprednisolone for neuroprotection has been studied extensively. Although some data support [16-20] its use in spinal cord injuries, others discourage it [21-24]. The current suggestion is that in CSI, methylprednisolone can be used for acute, nonpenetrating spinal cord injuries if the treatment could be started within 8 hours of injury [25]. However, it is not recommended for acute nonpenetrating spinal cord injuries older than 8 hours or penetrating spinal cord injuries [25]. The recommended dose is a 30-mg/kg

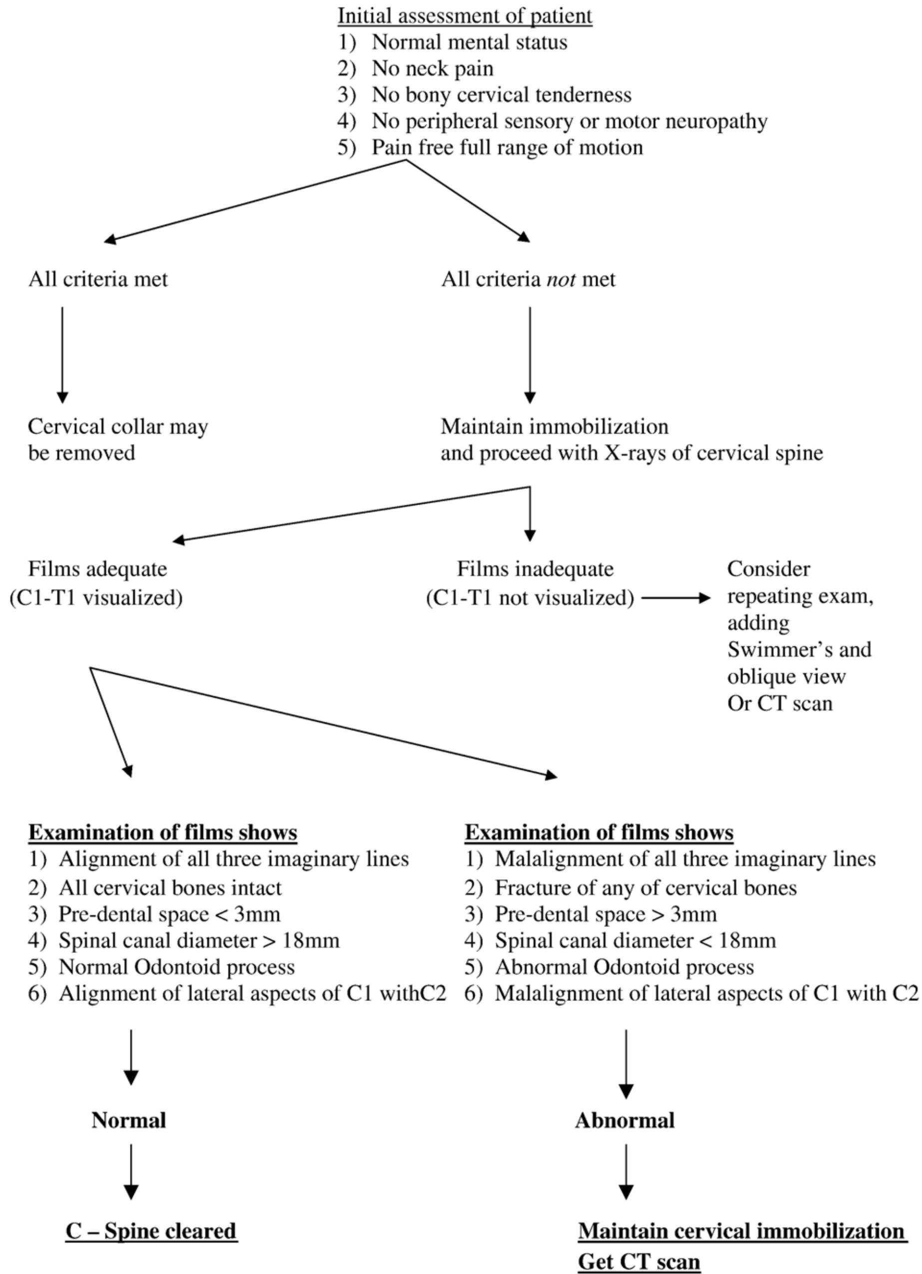

Fig. 1 A schematic approach to exclude CSI.

bolus, followed by 5.4 mg/kg for 24 hours if started within 3 hours or for 48 hours if started within 3 to 8 hours [26]. Given the devastating impact of neurological injury associated with CSI and the evidence of a modest, beneficial effect of methylprednisolone, clinicians should consciously consider using this drug despite the well-founded criticisms that have been directed against its use.

4. Guidelines for evaluation of the C-spine

These guidelines are applicable to all patients with trauma in whom the mechanism of injury is not clear, and injury to the C-spine cannot be ruled out. The guidelines are different for the fully conscious patients when compared with comatose and uncooperative patients (Fig. 1). Fully conscious patients include those who are not intoxicated and who are able to cooperate fully with a clinical examination. This excludes infants and young children, patients with significant pain, patients with mental retardation or other psychiatric illness, and patients with drug or alcohol intoxication that precludes full cooperation.

In patients who are able to cooperate fully, the C-spine may be cleared clinically if the following criteria are met [1,27]:

1. There is no neck pain.
2. There is no bony cervical tenderness.

3. There are no abnormal peripheral sensory or motor neurological findings on physical examination.
4. The patient is able to demonstrate a full range of neck movement without pain (side to side and flexion and extension).

However, even in these patients, the elimination of radiography could result in CSI (also National Emergency X-radiography Utilization Study) [28]. Given that CSI may be catastrophic to the patient, the decision not to use radiographs or computed tomography (CT) should be based both on clinical examination and the mechanism of injury, with the attending physician maintaining a high index of suspicion. The presence of a mechanism demands further imaging even in a normal clinical examination. Certainly, if these criteria are not met, a complete radiographic examination of the C-spine should be performed [29].

For the unconscious, intoxicated, or uncooperative patient, the C-spine cannot be cleared clinically by history and physical examination alone. All such patients with trauma with suspected CSI should have radiographic examinations of the C-spine. However, normal radiological examination will not entirely rule out CSI in these patients. The patient's clinical course determines their further diagnostic workup. For instance, patients expected to regain full consciousness within 24 hours should have their entire spine immobilized and treated as unstable until an adequate clinical examination can be performed. Patients unlikely to regain full consciousness within 24 hours should have further diagnostic examination with magnetic resonance imaging (MRI) or dynamic flexion/extension under image intensifier control [30,31].

In summary, a proportion of asymptomatic patients can be cleared clinically. The majority could be divided into low-risk or high-risk groups and includes both asymptomatic and symptomatic patients. A 3-view or 5-view plain film radiograph series can clear the C-spine of adequate technical quality in the low-risk group, whereas a 3-view and CT examination is suggested in the high-risk group.

5. Radiographic evaluation

Anesthesiologists are dependent upon radiologists to rule out CSI with the radiological examination. Although this is an accepted and standard practice, having some basic knowledge in interpreting plain films of C-spine is essential in emergency situations. An overview of the use of plain films, computed tomography, and MRI in CSI is discussed in the following paragraphs.

6. Choice of study

When diagnostic radiographic examination of the C-spine is indicated, initial cervical radiography includes plain films of the C-spine. The standard C-spine x-rays are commonly lateral, anteroposterior, and open-mouth (OM) (Fig. 2) views [32-34]. These views must adequately evaluate the levels of C1 to the C7 through T1 junction clearly. Some physicians are now recommending the trauma oblique view [35]. These are supine oblique views and they provide excellent visualization of the posterior elements, often down to thoracic level T2 through T3. Some authors recommend that all 5 radiographic views should be taken routinely [36]. The sensitivity of plain films even with additional views is in the range of 90% in actual CSI, which is further decreased in critically ill patients.

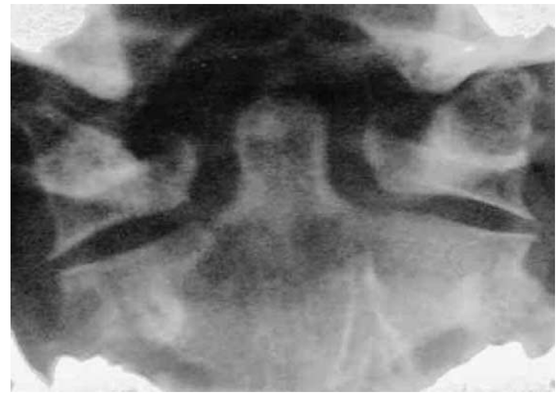

Fig. 2 Radiograph showing normal odontoid (OM) view.

In practice, the choice of series will vary according to institution and availability of CT scan in the facility [37]. As it is clear from the literature that no initial imaging modality is 100% accurate [3,38,39], further studies are often frequently required. If there is any doubt about the adequacy of the examination, a follow-up CT scan is strongly recommended. Although this may be focused on the level incompletely evaluated, commonly the craniocervical region (C1-2) or cervicothoracic (C7-T1) junction, we recommend scanning the entire C-spine if CT is performed [40]. Sagittal and coronal reconstruction views should also be reviewed as subluxation is often best seen in these planes. Many centers routinely perform only CT or a combination of a lateral film and CT on all patients who have any suspicion for CSI. The combined CT and plain film technique is the only technique which has a sensitivity of 99% to 100% for CSI.

Any patient with an abnormal peripheral neurological examination related to the C-spine should have an MRI [1,22,23]. Magnetic resonance imaging is a very sensitive study for soft tissue injuries including ligamentous injuries and posttraumatic lesions causing compression of the spinal cord or nerve roots such as disk herniations or hemorrhage [41-44].

7. Clinically important x-ray findings

7.1. Plain films

As with all radiological examinations, a systematic approach is necessary. The lateral view is the most important projection. It should visualize the entire cervical spinal column from the skull to the first thoracic vertebra. If the C7 through T1 junction is not visualized, then "swimmer's" view of C-spine, taken with 1 arm extended over the head, may allow adequate visualization of this region. The alignment of the C-spine is determined on the lateral film. The anterior and posterior margins of the vertebral bodies (anterior and posterior laminar lines; Figs. 3 and 4) and the tips of the spinous processes (spinolaminar line; Figs. 3 and 4) from the second cervical vertebra to the 7th cervical vertebra should be aligned. Confusion can sometimes result from pseudosubluxation (a physiologic misalignment that is due to ligamentous laxity), which can occur at the C2 through C3 level and, less commonly, at the C3 through C4 level. When the problem is at the C2 through C3 level, C2 may appear to be anteriorly displaced in relation to C3. Although pseudosubluxation usually occurs in children up to the age of 10 years, it also may occur in adults. If the degree of subluxation is within the normal limits (4-5 mm in children up to 15 years of age and 2-3 mm in adults) [45] and the neck is not tender at that level, flexion-extension views could be considered to exclude soft tissue injury. Pseudosubluxation should disappear with an extension view. However, flexion-extension views should not be obtained until CT scan otherwise clears the entire C-spine.

The lateral view should also include assessment of the skull base—C1 through 2 alignment—to exclude occipito-cervical dislocation. This is diagnosed by the presence of uncovered occipital condyles and misalignment of the foramen magnum and the C1 ring. A diagonal line drawn from the basion (anterior margin of the foramen magnum) to the tip of the dens should not exceed 12 mm. There is also typically increased prevertebral soft tissue swelling. The most accurate prevertebral measurement in an adult is anterior to the midpoint of C3, which should be less than 4 mm in an adult (exception heavily muscled or obese individual).

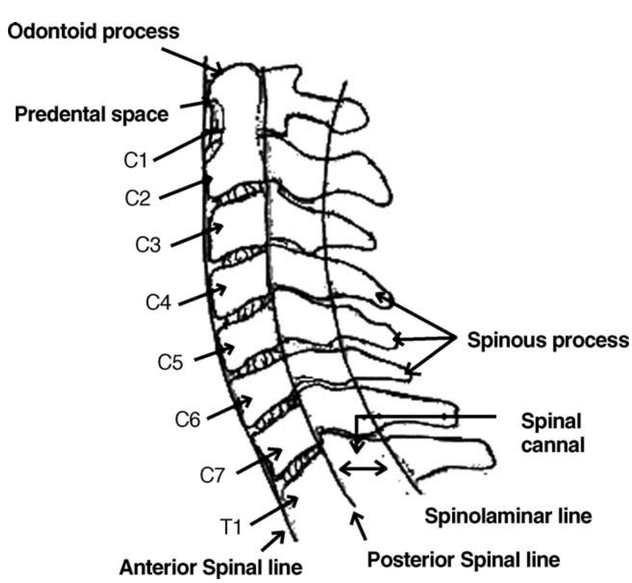

Fig. 3 Schematic diagram showing lateral view. Note the odontoid process, predental space, and the spinal canal.

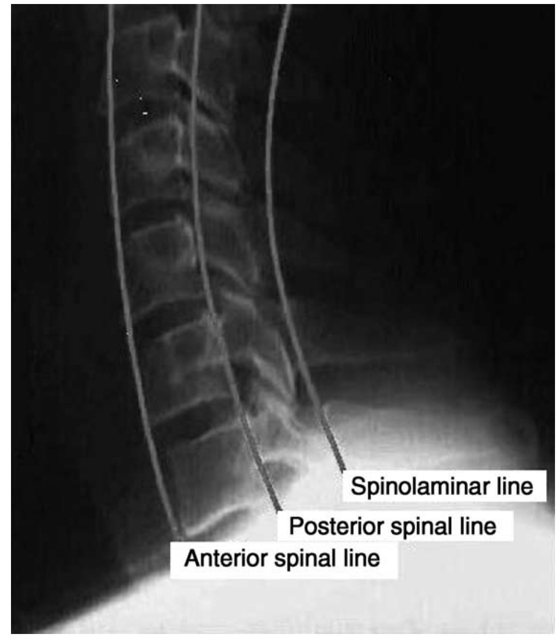

Fig. 4 Radiograph showing normal lateral view of C-spine. Note the anterior and posterior laminal lines and spinolaminar line.

The predental space (Fig. 3) between the dens and the anterior portion of the ring of the first cervical vertebra should be examined next. This space should be less than 3 mm in adults and 4 to 5 mm in children. The next step is to measure spinal canal diameter (Table 1), which lies between the posterior spinal line and spinolaminar line. This measurement should be >18 mm in adults. A decrease in this measurement is often seen with spinal canal stenosis; however, further imaging could be considered if clinically relevant symptoms exist as stenosis increases the chance of spinal cord injury even with a normal range of flexion and extension.

Spinous processes should be observed for any widening of the space between them (Table 1). Examination of the vertebral bodies and intervertebral disk spaces should be done, which will reveal compression and burst-type injuries if present. The vertebral bodies (except for the first and second cervical vertebrae) should be regular in shape and

Table 1 Measurable normal parameters of C-spines in adults

Parameters	Measurements
Predental space	≤3 mm
C2-3 pseudoluxation	≤3 mm
Retropharyngeal space	≤6 mm at C2
Angulation of spinal column	<11°
Spinal canal diameter at any single interspace level	≥18 mm

should be of same size as the vertebral body immediately above and below.

The next radiograph to study is the OM view. The OM view is critical in the evaluation of C1 through C2. The dens should be symmetrically located between the lateral masses of C1 with no abnormality within its contour and at its base. There should be no "overhang" of the lateral masses lateral to the body of C2. Artifacts may give the appearance of a fracture. These artifacts are often radiographic lines caused by the teeth overlying the dens, which cause the appearance of longitudinal fractures. However, fractures of the dens are unlikely to be longitudinally oriented. If there is any doubt about the possibility of a dens fracture, thin section CT scan is indicated.

The frontal anteroposterior view provides corroborative evidence for flexion injuries and for facet dislocation. This is the only view which visualizes the uncinate process.

If there is any misalignment, ligamentous injury or occult fracture should be considered, and C-spine immobilization should be maintained while further examinations are ongoing.

As discussed, any doubt about an abnormality on the plain radiograph or if the patient has disproportionate neck pain warrants a CT scan of the concerned area or the entire C-spine. The presence of a fracture at any site also warrants CT examination of the entire spine. The CT scan should ideally be performed with sections less than 3 mm thick. Sections measuring 1 mm with reconstructions are obtained and reviewed at our institution. The CT scan is excellent for identifying osseous abnormalities including fractures and subluxation but is not a good study to diagnose soft tissue injuries [46]. Magnetic resonance imaging, although better at identifying soft tissue injuries, requires a greater degree of patient cooperation and immobility, has several restrictions such as resuscitation equipment with metal parts in the acute traumatic setting, and takes longer to perform. Thus, it is as an adjunct to plain films and CT scanning [47] and typically used only after CT examination and stabilization of the patient.

Even when there is no radiographic evidence of CSI, the possibility of a neurologically significant cervical cord injury still exists. A special entity called "spinal cord injury with out radiographic abnormality" (SCIWORA) syndrome occurs when the elastic ligaments of the neck are stretched during trauma [48]. The ensuing stretching of the spinal cord can cause neurological injury. In some cases, complete severing of the spinal cord can occur. This syndrome may account for 70% of spinal cord injuries in children younger than 8 years. It is important to inform the parents of a young child with trauma about this possibility and to perform serial clinical neurological examinations. Fortunately, most children with the SCIWORA syndrome recover fully [49]. The treatment modalities of SCIWORA syndrome are not extensively studied, but the general consensus is that pharmacologic management with high-dose steroids is the most efficacious [50].

Once the radiological status of the C-spine is determined using these criteria, anesthetic management may proceed with due attention to other associated factors (eg, possibility of full stomach and hemodynamic instability).

8. Considerations for airway management and anesthesia

For an anesthesiologist, the first interaction with the CSI patient may be because of an urgent request to assist with the airway management. On occasions, the CSI patient might require anesthesia for an elective or emergent surgery. In addition to the standard airway and anesthetic evaluation, a brief neurological examination to assess the extent of CSI is important. Attention should also be given to the possibility of unstable hemodynamics due to spinal cord injury at the cervical level. Hemodynamic changes could manifest as profound bradycardia, hypotension, and pseudohypovolemia (due to absence of vasoconstriction). Several other likely anesthetic concerns could include possibility of full stomach, head injury with elevated intracranial pressure, a skull base fracture, edema of the higher cardiorespiratory centers, compressed airway due to the a cervical hematoma [51], bleeding from other injuries and associated inappropriate volume status, and uncooperative and combative patient. There is no "right" way, and the "best" approach will be determined by the relative weight of these limiting factors.

Securing the airway, assuring adequate gas exchange, and stabilizing the circulation are initial priorities, which should take precedence over other issues. Airway obstruction may be relieved with chin lift or jaw thrust maneuvers, which should be done with caution while avoiding head tilt. Simple maneuvers such as these can delay the necessity for mask ventilation and/or intubation while other assessments and/or treatments are ongoing. If the airway is patent, emergent intubation is not required if the spinal lesion is below C6 because the diaphragmatic control of breathing remains intact.

Anesthesiologists play an important role in managing patients with hemodynamic instability. In the presence of hemodynamic instability, evaluation of the C-spine can be safely deferred, as long as the C-spine is secured and protected. Because the cardiac accelerator fibers arise from T1 through T4, higher levels of spinal injury may be associated with hemodynamically significant bradycardia. The normal tachycardia in response to hypotension may be blocked. A "relative" hypovolemia also exists because of an increase in venous capacitance resulting from functional sympathectomy. Intravenous replacement therapy to maintain systolic blood pressure between 80 and 100 mm Hg should be initiated [52].

If the level of injury is above T7, the level of adrenal response to stress is decreased, which can also cause hypoglycemia along with hypotension and bradycardia.

The risk of cardiac arrest is increased during attempted endotracheal intubation especially in children because of vagal stimulation. This risk can be attenuated by pretreatment with appropriate doses of atropine or glycopyrrolate. When there is uncertainty regarding the integrity of the C-spine, direct laryngoscopy (with vigorous atlantooccipital extension) should be avoided unless the urgency of airway control demands it. Axial traction, which was once recommended, has now been replaced by "in-line stabilization."

An assistant is needed to hold the occiput down on the backboard with both hands. This maneuver, if properly performed, minimizes the flexion-extension movement and also decreases the rotation movement in the C-spine. However, there is no question that in-line stabilization, when correctly performed, will make direct laryngoscopy and intubation more difficult. Although it serves to decrease the movement in the atlantooccipital joint, which decreases the chance of neurological injury, the same maneuver prevents the movement necessary to allow better visualization of the glottic opening.

Various techniques for minimally invasive intubation can be used [53,54]. These include flexible fiberoptic laryngoscopy, retrograde wire techniques, blind nasotracheal intubation, light wand, and Augustine guide–aided intubations (Augustine Medical, Inc, Eden Prairie, Minn) and intubations using the Bullard laryngoscope (Bullard Laryngoscope; Circon Corporation, Stamford, Conn). All these techniques have some disadvantages. For example, flexible fiberoptic laryngoscopy is difficult to perform in the combative and uncooperative patient, and blind nasotracheal intubation is contraindicated in basal skull fracture. Nevertheless, the varieties of techniques available provide many relatively safe approaches to airway control.

Some authors recommend a flexible fiberoptic bronchoscope (FOB) for initial intubation of these patients [55] with a reported success rate of nearly 100% [56]. Others emphasize limitations of the FOB, noting that it is technically difficult to use [57]. In one study, FOB intubation in an emergency department was successful in only 72% of the cases [58].

Endotracheal intubation using the Bullard laryngoscope may have some advantages over other techniques as it causes less head and C-spine extension than conventional laryngoscopes and results in a better view [59]. One study comparing the use of Bullard laryngoscope with FOB in patients with unstable C-spine concluded that awake endotracheal intubation in patients at risk for neurological injury during intubation may be reliably accomplished with the Bullard laryngoscope more rapidly than with a FOB [60]. The use of the Bullard laryngoscope, however, appears to be more difficult in micrognathic patients with coexisting neck immobility [60].

Another interesting study showed that the C-spine extension and time to intubate are similar for the Macintosh

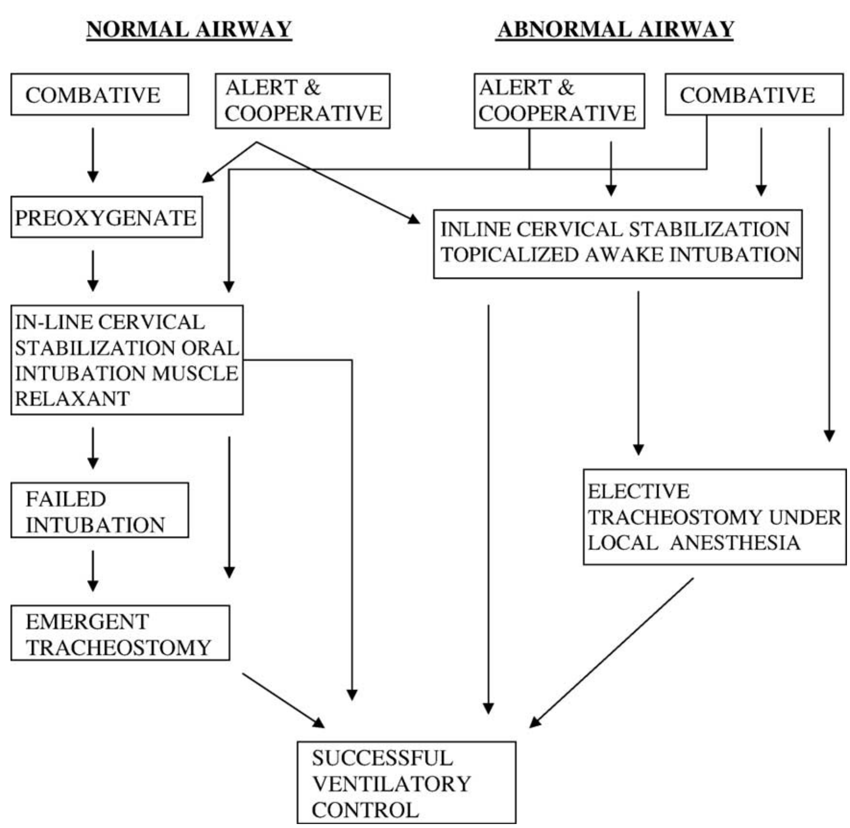

Fig. 5 Anticipation as a part of decision making.

laryngoscope with in-line stabilization and the Bullard laryngoscope without in-line stabilization. However, time to intubate was significantly prolonged when the Bullard laryngoscope was used in a simulated emergency with C-spine precautions taken [61].

The available data to define the role of Laryngeal Mask Airway (LMA North America, San Diego, Calif) in patients with trauma is insufficient. The magnitude of spinal movements caused by manipulation during Laryngeal Mask Airway insertion in these patients was not great, but there is concern about the high pressure generated against the upper C-spine [62,63].

The need for surgical access to airway (tracheostomy using local anesthetic) should be recognized immediately and should be performed by an experienced physician without delay. It may be used as a primary airway when injuries to the pharynx are present or after unsuccessful orotracheal intubation. It can either be obtained by an open surgical approach or via a percutaneous needle cricothyroidotomy.

There are no data to suggest categorically better outcomes with any particular technique. Rather, it is likely that vigilance, maintenance of spinal immobilization, and appropriate management of associate problems are important factors in limiting the risk of secondary neurological injury than any particular technique. We believe that for a nonurgent and elective airway control, awake fiberoptic intubation technique should be used. This technique has an added advantage that the head and neck stabilizing devices can be left in place, and it does not depend on atlantooxipital extension. However, for emergent access of airway, our opinion is that oral intubation using a Macintosh blade after intravenous induction of anesthesia and muscle relaxation using inline stabilization is the safest and quickest way to achieve intubation in a patient with suspected CSI. However, anticipation is a major component of decision-making in a patient with CSI (Fig. 5), and the best method must be chosen using all available clinical data.

Although there are reports [64,65] of worsening neurological injury after induction and direct laryngoscopy and intubation in patients after neck injury, it is difficult to predict the incidence of bad neurological outcomes in such cases that could be attributed to anesthetic management. The type and location of the CSI, along with hemodynamic stability, would influence the neurological outcome after intubation [64,66,67]. Coelho et al [66] suggested that bilateral facet dislocations and burst fractures have a greater risk of spinal cord lesion in lower C-spine trauma when compared with unilateral facet dislocations and other types of osteoligamentous lesions. It is also a known fact that efficiently performed direct laryngoscopy produces little movement below C3 [68]. Spinal cord autoregulation is believed to be unreliable in injured spinal cord, and hypotension can cause cord ischemia [69]. In some patients, the spinal cord blood flow may be so unstable that even maintaining normotension while performing awake intubation along with interventions to maintain stable C-spine is still insufficient to prevent quadriparesis [70].

In conclusion, although outcome might vary depending on the clinical presentation, the goal for any anesthesiologist irrespective of the type, location, and severity of the CSI, the primary goal at the time of induction, laryngoscopy, and intubation, would be the same, hemodynamic stability with maintenance of stable C-spine. In addition, depending on the clinical presentation, the role of methylprednisolone in neuroprotection should be considered.

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