Chapter 18

INJURIES TO THE FACE AND NECK

MICHAEL D. MATSON, M.D.*

Lieutenant Colonel, Medical Corps, U.S. Army; Staff Anesthesiologist, Walter Reed Army Medical Center, Washington, D. C. 20307-5001

INTRODUCTION

Anesthesiologists in both the civilian and military communities sometimes encounter casualties with trauma to the face and neck. In the civilian sector, injuries to the face and neck are most commonly the result of blunt trauma from automobile and motorcycle accidents. In the military, injuries to the face and neck are primarily the result of penetrating missiles. During World War I, facial injuries often occurred when soldiers were (*a*) shot in the head as they peered out of their trenches[1] or (*b*) struck by large chunks of metal from the detonation of random-fragmentation shells. Such traumata were usually rapidly fatal because the missile, by virtue of its high kinetic energy, did not stop on entering the soldier's face or neck but continued on into the brain or cervical spine (Figure 18-1).[2]

Fig. 18-1. Wounds of the face caused by high-velocity missiles have a propensity to involve the nearby anatomical structures. This soldier was killed during the Vietnam War when a bullet fired from an AK47 (7.62 mm) entered his lower jaw, passed through the fifth cervical vertebra, and transected his spinal cord. Photograph: Wound Data and Munitions Effectiveness Team slide collection.

Injuries to the face and neck in more recent military conflicts such as the Vietnam War have increasingly been the result of so-called improved fragmentation munitions such as grenades, mortars, and artillery shells.[1,3] Improved fragmentation munitions are designed to generate large numbers of small (< 1 cm), light (< 1 g) fragments. Thus, the typical *living* casualty in a modern war who has ballistic trauma to the face or neck—and who survives long enough to be evacuated from the battlefield—has one to a few benign-appearing wounds. The damage appears to be limited to a sinus, an orbit, a few teeth, or the soft tissue of the pharynx or neck. Nevertheless, these benign-appearing injuries may be life threatening (Figure 18-2).

Casualties with face and neck wounds can challenge the anesthesiologist. Establishment of an airway and adequate ventilation in these patients can be difficult (Figure 18-3), and supervenient factors such as the following can complicate management:

- hemorrhage,
- risk of aspiration,
- associated injuries,
- difficult intubation,
- tissue debris and foreign material obstructing the airway, and
- an unstable cervical spine.

Associated injuries—especially those of the head, but also those to other parts of the body—are common. Once the airway is secure, care of the associated injuries will frequently be more immediately important than care of the actual face and neck injuries themselves. Management of casualties with multiple injuries can be complicated by hemorrhage, hypovolemic shock, increased intracranial pressure, or disturbances of other body systems. The care of these patients, as with other trauma patients, should be in accordance with Advanced Trauma Life Support (ATLS) guidelines.[4] The perioperative management of casualties with injuries to the face and neck should follow this sequence of steps:

1. Assess the airway and establish patency, if necessary.
2. Assess breathing and provide or support ventilation, if necessary.

a b

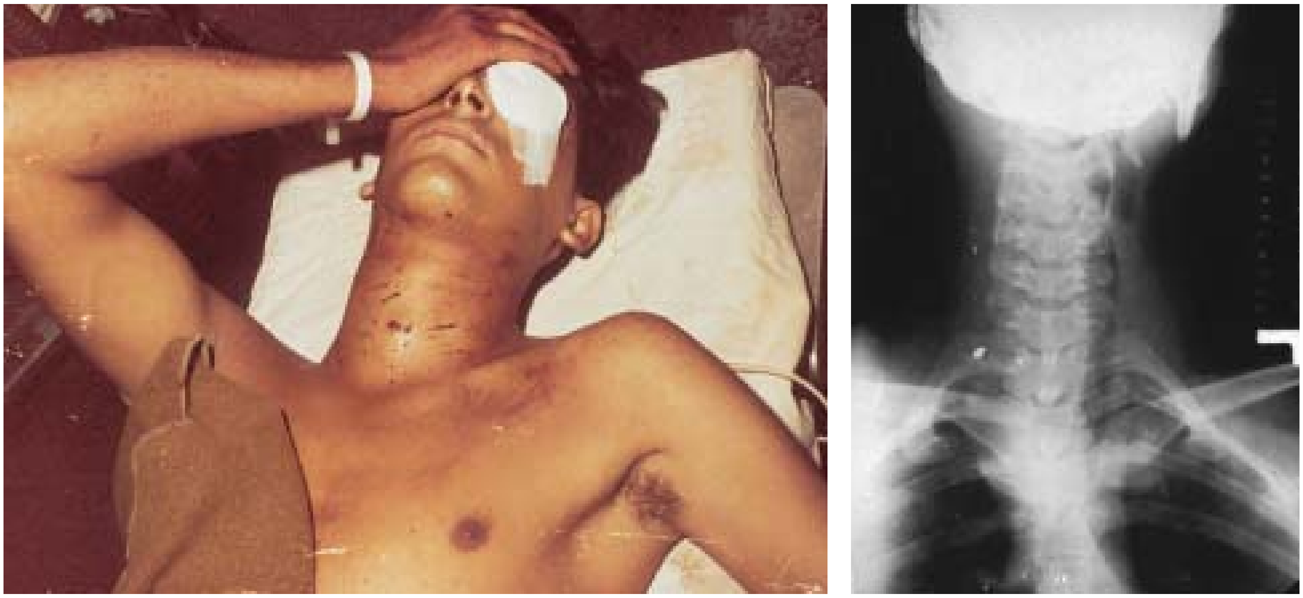

Fig. 18-2. (**a**) This casualty was wounded during the Vietnam War by three small fragments produced by an exploding, improved-fragmentation hand grenade. One fragment entered his left orbit and caused an injury that was treated by enucleation. Two additional fragments struck the right side of his neck, where one lacerated the right common carotid artery. (**b**) The radiograph (taken at the third-echelon surgical hospital) clearly shows how the expanding hematoma caused tracheal displacement. This casualty was treated before his airway was compromised. Photographs: Wound Data and Munitions Effectiveness Team slide collection.

a

b

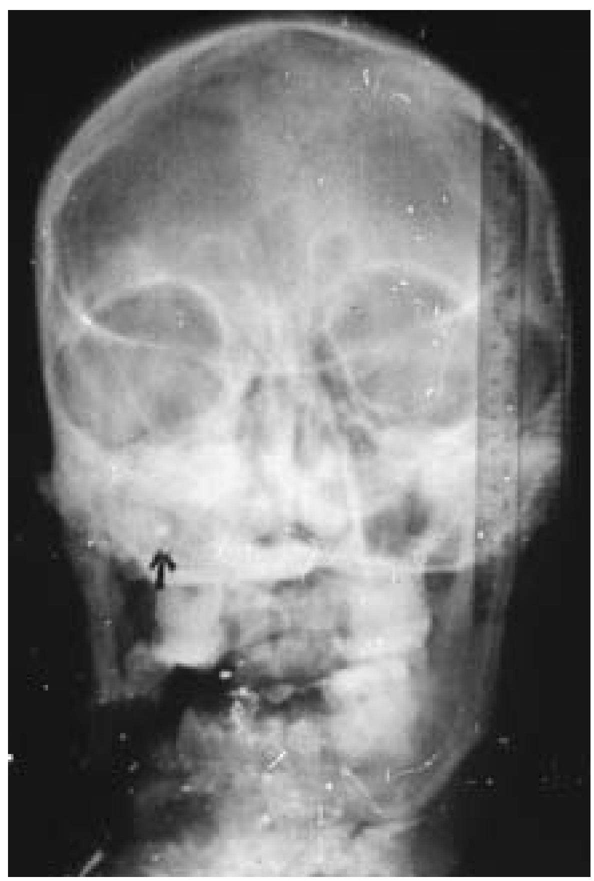

Fig. 18-3. (**a**) This casualty from the Vietnam War sustained a tangential gunshot wound of the right side of his face. Obstruction of his airway by blood and tissue fragments indicated the need for immediate airway control, but neither oral nor nasal intubation was possible in the field. The casualty was transported in the prone position (to prevent aspiration of blood) until an emergency tracheotomy could be performed at a third-echelon surgical hospital. (**b**) The great destruction caused by the gunshot wound is apparent in this anteroposterior radiograph. Note that a goodly portion of the right mandible is missing. Many artifacts are present in the radiograph; however, the arrow indicates a fragment in the casualty's maxillary sinus. Photographs: Wound Data and Munitions Effectiveness Team slide collection.

3. Assess circulation and control life-threatening bleeding.
4. Assess the level of consciousness and pupillary size and reaction.
5. Provide resuscitation as needed.
6. Evaluate in detail for
   - head and neurological injury,
   - maxillofacial injury,
   - neck injury,
   - chest injury,
   - abdominal injury,
   - genitorectal injury,
   - injury of the extremities, and
   - other injuries.
7. Prioritize injuries and plan coordinated, definitive care.

FACIAL FRACTURES

Fractures are common in facial trauma. Low-energy blunt impacts tend to cause isolated fractures (ie, fractures of the nose or mandible). High-energy blunt or penetrating impacts can cause panfacial or multiple fractures (ie, combinations of Le Fort fractures, naso-orbital-ethmoid fractures, and frontal bone fractures).

Mandibular Fractures

Mandibular fracture are common facial injuries. In the military, mandibular fractures can occur as a result of vehicular trauma, fragmentation blasts, and other causes. The force of the impact is redistributed as the mandible is fractured and displaced; thus, skull fractures are less common with mandibular fractures than with maxillary fractures.[1] Fractures of the mandible may be unilateral, bilateral, or comminuted. Unilateral fractures are relatively stable. Bilateral and comminuted fractures tend to be unstable. Patients with displaced fractures of the mandible present with malocclusion. They may also have pain, swelling, crepitation, and drooling. Loss of support for the base of the tongue can lead to airway obstruction, as can edema and hematomas. Trismus secondary to pain, edema, or hematomas can occur with mandibular fractures and can greatly complicate airway management. The swallowing mechanism can be impaired and that, combined with bleeding and hypersecretion of the salivary glands, can increase the risk of aspiration. Patients with mandibular fractures are also likely to require intermaxillary wiring, which further complicates perioperative airway management.

Nasal Fractures

Nasal fractures are also common facial injuries. Signs of nasal fracture include nasal deformity, epistaxis, hematoma of the nasal dorsum, and crepitance of the nasal bone. Significant hemorrhage can occur with nasal fractures and, in the obtunded patient, can lead to airway obstruction or aspiration. Obstruction of the nasal air passage can also occur as a result of bony deformities and edema. Blind nasal intubation should be avoided in patients with nasal fractures or intranasal injuries. If nasal intubation is required, then evaluation of the nasal passage via fiberscope or other means should precede tube placement.

Maxillary Fractures

Maxillary fractures are common in civilian practice (eg, automobile accidents). In the military, maxillary fractures might occur if a truck were to detonate a mine. These injuries are generally caused by high-energy trauma and are often associated with skull fractures or intracranial injuries. As the maxilla is a very vascular structure, fracture and disruption can cause significant bleeding both preoperatively and intraoperatively. Manifestations of maxillary fractures include malocclusion, marked facial swelling, mobility of the midface, palpable malalignment of the bone edges (ie, step-off deformities) at the fracture site, and ecchymosis. A variety of maxillary fracture patterns can occur in severe facial trauma, but classically three patterns, the Le Fort fractures, are described (Figure 18-4).[5]

The Le Fort I fracture involves the lower midface and may be unilateral or bilateral. The fracture line is located above the level of the teeth but below the nose. The teeth and hard palate are separated from the upper portions of the maxilla. The lower portion of the maxilla is mobile. Occasionally, the lower portion will be fractured at the midline into two segments.

The Le Fort II (ie, pyramidal) fracture is located at a higher level than Le Fort I fractures. The fracture line generally passes through the nasal bone, the lacrimal bone, the floor of the orbit, the infraorbital margin, and across the upper portion of the maxillary sinus and pterygoid plates to the pterygopalatine fossa. The maxilla is "free floating" in this fracture.

The Le Fort III fracture results in complete separation of the facial bones from their cranial attachments. The fracture line is high in position and extends across the nasofrontal suture and through the upper orbits. The main fracture segment is the entire midface. Le Fort II and III fractures are commonly associated with intracranial injuries, cribriform plate injuries, dural tears, and cerebrospinal fluid leaks.

Zygomatic Fractures

Fractures of the zygoma are less severe than maxillary fractures. However, displaced bony fragments may impinge on the coronoid process of the mandible and make opening the mouth difficult and painful. This can complicate airway management. Other signs of zygomatic fracture include ophthalmological abnormalities, flattening of the cheek, bony step-off deformity, and ecchymosis.

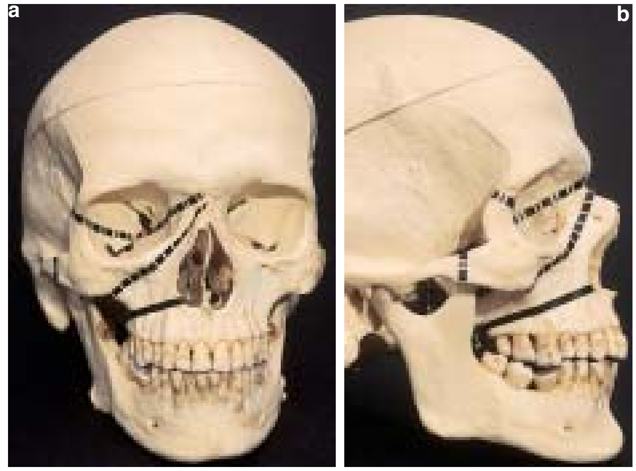

Fig. 18-4. (**a**) Anterior view of typical Le Fort I fracture lines (bottom line), Le Fort II fracture lines (center line), and Le Fort III fracture lines (top line). (**b**) Lateral view of the typical Le Fort fracture lines.

NECK INJURIES

The neck region contains a number of critical neurological, vascular, and airway structures in a relatively small space. Blunt and penetrating trauma to the neck can cause a wide variety of injuries, ranging from minor to severe to life threatening. Neck injuries in the military setting carry a 10% to 15% mortality.[6] Airway injury, vascular injury, and cervical spine injury can rapidly lead to death. If not properly managed, esophageal injuries can lead to serious infection, sepsis, and death. Quick and effective medical management can be lifesaving in some of these casualties.

The neck is commonly divided into three anatomical sections, one above the next.[7] Zone I, the lowest section, is the area behind the clavicles up to the cricoid cartilage. Zone I contains portions of the major vessels from the chest as well as portions of the lung apices, upper mediastinum, trachea, esophagus, and thoracic duct. This zone is partially protected by the clavicles. Zone II is bounded by horizontal planes at the level of the cricoid cartilage below and the angle of the mandible above. This section contains portions of the airway, esophagus, major blood vessels, cranial and peripheral nerves, cervical spine and spinal cord, and other structures. Zone II is relatively vulnerable to injury because the only bony protection is the cervical vertebral column to the rear. Zone III is the section between the angle of the mandible below and the base of the skull above. This zone contains many of the same structures as zone II, but surgical exposure is much more difficult in this region.

Neck injury can be caused by both blunt and penetrating trauma. Examples of blunt trauma are vehicular accidents and falls. Sources of penetrating trauma are gunshots, fragmentation blasts, knife wounds, and high-speed vehicular accidents.

Casualties with neck injuries require rapid evaluation to assess airway injury or compromise, ventilation, vascular injury, esophageal integrity, and neurological function. As with other injuries, the first priority is to ensure that the casualty has a secure airway and adequate ventilation. The possibility of cervical spine injury must be considered in every instance. In some cases, urgent intervention is required to stabilize the casualty. In others, the casualty can be monitored while injuries are evaluated in more detail and a surgical plan is developed. Expedient surgical exploration of penetrating neck injuries is indicated if the medical officer suspects vascular, airway, esophageal, or neurological injuries, or a missile path that crosses the midline.[8]

Airway Injuries

Potential injuries to the airway in neck trauma include crush injuries of the laryngeal structures and cricoid cartilage; tears, fistulae, lacerations, and transection of the trachea; bleeding and mucosal edema in the airway; and vocal cord obstruction due to nerve injury or arytenoid dislocation. The airway can also be compressed and obstructed by adjacent hematomas and subcutaneous emphysema in the neck.

Airway injuries can rapidly lead to death in the field before the casualty can be transported to a medical facility. Casualties with airway injuries may present for emergency treatment in severe respiratory distress. They can also present with what appears to be minor respiratory compromise and can, over a period of hours, insidiously develop airway obstruction from expanding hematomas or edema. The airway should be secured early if any signs of distress are present. This topic is discussed more fully in Chapter 3, Airway Management.

The integrity of the larynx can be disrupted by crush injuries from blunt trauma or from damage to the cartilage or supporting structures from penetrating trauma. Blunt trauma can also damage or collapse the cricoid cartilage and can cause tearing or total disruption of the cricotracheal junction. Penetrating trauma can tear, lacerate, or transect the trachea at any level. If the trachea or laryngeal structures are damaged, the airway must be secured below the lowest level of the injury. A tracheostomy can be done on an emergent basis, if necessary. Cricothyroidotomy is contraindicated if the cricothyroid area is damaged or if the trachea is damaged, as the canula could easily be placed into a false passage. With a tracheostomy, the surgeon may be able to get below the level of the tracheal injury and avoid placing the canula into a false passage. A transected trachea requires rapid surgical exploration and retrieval of the retracted distal segment. If time allows, casualties with airway injuries can potentially be intubated using a fiberoptic technique.

Vascular Injuries

Vascular injuries are common in penetrating neck trauma[9] and relatively uncommon in blunt neck trauma. Arterial injuries can lead to exsanguination, cerebral ischemia, and hematomas that can compress the airway. Venous injuries can lead to exsanguination or air embolism. Rapid exsanguination and loss of large volumes of blood into the chest can occur if the major vessels in zone I are disrupted. Fistulae from blood vessels to the airway can lead to massive pulmonary aspiration.

If time allows, preoperative angiography will help define the extent of the vascular injury. Early airway control will be needed if the patient has hemodynamic instability, neurological compromise, or bleeding into the airway. If the casualty is unstable, then rapid surgical control and resuscitation will be needed. The anesthesia team and surgical team must keep each other apprised of the patient's condition, ongoing blood loss, adequacy of control of bleeding, and the status of both blood-component and volume resuscitation.

Intraoperatively, continuous processed electroencephalography is valuable in monitoring for global cerebral ischemia during arterial clamping and repair. In addition, maintenance of a normal blood pressure will help maximize cerebral blood flow via collateral routes when one of the carotid or vertebral arteries is compromised.

There is a potential for air embolism if the internal jugular vein is disrupted. This can be a fatal complication if massive air aspiration occurs. The patient should be monitored for onset of air embolism with a precordial stethoscope, continuous respiratory-gas analysis, and precordial Doppler probe, if available. Transesophageal echocardiography is an extremely sensitive monitor of venous air embolism. Treatment of venous air embolism, should it occur, includes head-down positioning of the patient; flooding the surgical field; aspiration of air from the right atrium with a multiorifice central venous catheter; discontinuation of nitrous oxide, if it is being used; and hemodynamic support, if needed.

Nerve Injuries

Neurological structures that can be injured in neck trauma include the spinal cord, brachial plexus, phrenic nerves, cranial nerves, and sympathetic fibers. Spinal cord injuries are discussed below in the section on cervical spine injuries. Brachial plexus injuries can result in upper-extremity weakness and paresthesia. Causalgia is a common late complication of brachial plexus injury. Phrenic nerve injury leads to paralysis of the hemidiaphragm. Injury of the vagus nerve or the recurrent laryngeal nerve can result in vocal cord paralysis, which can contribute to airway obstruction. Injury of the vagus nerve or superior laryngeal nerve may abolish sensation above the vocal cords and can blunt protective airway reflexes.

Esophageal Injuries

Esophageal injuries occur more frequently with penetrating than with blunt neck trauma. Disruption of the esophagus can easily lead to infection that spreads to the mediastinum and becomes life threatening. Fistulae between the esophagus and the trachea, or between the esophagus and the blood vessels, occasionally occur. Esophageal tears and lacerations require early surgical diagnosis and repair.[10]

CERVICAL SPINE INJURIES

Injuries to the cervical vertebrae can occur when soldiers fall from a height, have direct penetrating trauma to the neck, or suffer head and face injuries or multiple trauma. The incidence of serious cervical spine injury in patients with major trauma varies from 1% to 3%.[11] Because of the potential for permanent injury to the cervical spinal cord, cervical spine trauma can be devastating. Medical personnel must carefully protect the cervical spine from the time of their first contact with the soldier until such time as injuries to the cervical vertebrae and spinal cord are either ruled out or definitively stabilized. Spinal cord injury can occur during field stabilization, transport to the hospital, airway management, or at any other time in the early phases of care. Initial care requires immobilization of the neck, control of the airway, assessment of cervical spine stability, and evaluation of neurological damage. Subsequent care involves restoration of anatomical integrity of the cervical vertebral column if required, continued protection of the cervical spinal cord, and rehabilitation. Injuries to the cervical spine and spinal cord are also discussed in Chapter 1, Combat Trauma Overview, and are the subject of Chapter 16, Neurological Injuries.

Cervical Vertebral Injuries

There are seven vertebrae (C-1 through C-7) in the neck. They provide support for the skull and protection for the cervical spinal cord. C-1 and C-2 are unique in structure and function. C-1, the atlas, consists of anterior and posterior arches and has no protruding articular processes. It articulates with the occipital condyles of the skull above and with C-2 below. C-2, the axis, has an anterior upward protrusion called the dens or odontoid process. C-2 has downward-protruding articular processes posteriorly. The dens and the articular surfaces articulate with C-1 above. C-2 articulates with C-3 via the articular surface of the body anteriorly and protruding articular processes posteriorly. C-3 through C-7 are similar in structure. Each vertebra consists of a body anteriorly, articular processes to the sides, and a spinous process posteriorly. Pedicles connect the body to the articular processes; laminae connect the articular processes to the spinous process. C-2 to C-7 articulate with each other via the posterior articular processes. The bodies of C-2 to C-7 are linked by intervertebral discs. The cervical vertebral column is strengthened by numerous ligaments.

The cervical spine is the most mobile and the least protected portion of the vertebral column, and is susceptible to injury from blunt and penetrating trauma. Instability of the cervical spine can result from fractures of portions of the vertebrae or disruption of the supporting ligaments. Compression fractures of the vertebral bodies and fracture-dislocations of the articular processes can cause cord compression and injury. Chin, mandibular, and zygomatic injuries are more commonly associated with injuries of the upper cervical spine, whereas upper-face and scalp injuries are more commonly associated with injuries of the lower cervical spine.

Cervical Spinal Cord Injuries

In the cervical region, the spinal cord occupies two thirds of the vertebral canal. Anterior and posterior nerve roots exit the spinal cord at intervals. The anterior roots have somatic fibers that control muscle movement, and the posterior roots have afferent fibers that carry sensory impulses.

Spinal cord trauma can occur directly, as a result of penetrating injury, or indirectly, from cord compression due to cervical fractures or dislocations. From 30% to 70% of patients with significant cervical spine injury may have associated spinal cord injury.[12] Compression of the spinal cord leads to vascular insufficiency, ischemia, edema, and neuronal cell death. Cord injuries can be complete, in which case no neurological impulses pass through the level of the injury, or they can be incomplete, in which case partial neurological deficits are present. Injuries to the brainstem or the upper cervical spinal cord are often fatal because of interruption of respiration and other vital functions. The innervation of the diaphragm is at the C-3 to C-5 level. Thus, injuries to the spinal cord at these levels or higher lead to respiratory failure. Injuries to the lower cervical spinal cord can interrupt intercostal muscle function, which seriously impairs pulmonary function.

Injury to the anterior portion of the spinal cord damages the spinothalamic and corticospinal tracts. Deficits include paralysis with loss of pain and temperature sensation. Injury to the posterior spinal cord is less common. Deficits include varying degrees of sensory loss and impairment of the positional and vibratory senses. In the Brown-Sequard syndrome, one side of the spinal cord is damaged. Deficits include motor weakness on the side with the lesion and pain and temperature sensory insensitivity on the side opposite the lesion. The Brown-Sequard syndrome can occur with penetrating trauma and with certain subluxation or dislocation injuries of the cervical vertebrae.

Spinal cord injury can cause a condition known as spinal shock. Disruption of the sympathetic fibers at the cervical cord level results in vasodilation, bradycardia, and hypotension. This condition occurs early in the injury and lasts several days to weeks. If spinal cord function does not recover, this syndrome gives way to autonomic hyperreflexia, a condition in which hyperresponsive autonomic reflex loops develop in the isolated lower level of the spinal cord. These conditions greatly complicate the perioperative management of casualties with spinal cord injuries.

Because spinal cord injuries are often permanent and devastating, every effort must be made to identify cervical spine instability and to protect the spinal cord during medical treatment.

Evaluation of Cervical Spine Injuries

Soldiers with any of the following conditions need radiological evaluation to rule out cervical spine injury[13]:

- multisystem trauma,
- blunt facial or head trauma,
- altered sensorium or neurological deficits,
- serious facial or scalp lacerations,
- fractures above the clavicles,
- traumatic neck pain or tenderness, or
- penetrating neck injuries.

An exception to this policy is patients who are fully alert, who do not have neck pain or tenderness, and who do not have other painful injuries that would mask neck pain. The standard radiological evaluation of the cervical spine consists of three views: cross-table lateral, anteroposterior, and open-mouth odontoid. All seven cervical vertebrae must be fully imaged on the cross-table lateral and anteroposterior views. Computed tomography views of the cervical vertebral column should be obtained if the plain views are inadequate or questionable, or if a neurological deficit is present.[13] Computed tomography is also indicated in patients with high-energy penetrating trauma to the cervical spine.[14]

Management of Blunt Cervical Spine Injuries

Initial care of soldiers with potential blunt cervical spine injuries should follow ATLS guidelines. At first contact with such a soldier, medical personnel should immobilize the neck, and, if necessary, the airway should be stabilized. Some casualties will require urgent airway intervention. Airway management must be approached with great caution because the risk of permanently injuring the cervical spinal cord is ever present. The most common methods of securing the airway in casualties with potential cervical spine injuries are oral intubation with cervical spine immobilization and blind nasal intubation. These techniques and other airway-management options are discussed later in this chapter.

Anesthesia providers must be concerned with more than just securing the airway in casualties with possible cervical spine injuries: they must carefully protect the cervical spine and the spinal cord during the perioperative period. The neck must be maintained in a neutral alignment during transport and positioning. Protection of the spinal cord also involves maintaining perfusion pressure and oxygenation. If spinal cord injury has occurred, high-dose methylprednisolone has been shown[15] to be of value in improving neurological outcome in some patients. Recovery from spinal cord injury depends on

- the extent of the initial injury,
- prevention of further injury, and
- avoidance of hypoxia and hypotension.

Spinal shock sometimes complicates the care of casualties with spinal cord injury. It is a syndrome that can be seen in the acute phase of spinal cord injury. The sympathetic system is disrupted by the injury and the casualty develops bradycardia, vasodilation, and hypotension. Profound hypotension is brought on by blood loss and positional changes. Fluid loading, atropine, and vasopressors may be required to treat spinal shock. Patients with spinal shock quickly develop pulmonary edema in response to fluid overload. Invasive monitoring can help guide fluid management in the perioperative period.

Over a period of days to weeks, the syndrome of spinal shock gives way to a chronic condition known as autonomic hyperreflexia. This is a syndrome of hyperreactive autonomic reflexes that sometimes develops in casualties with cord injuries above the T-6 level. Unchecked reflexes in the isolated spinal cord cause dramatic vasoconstriction and hypertension to occur in response to various stimuli. Autonomic hyperreflexia can be blocked by regional or general anesthesia and can be treated with potent vasodilators.

Patients with spinal cord injuries also have problems with temperature regulation. Careful temperature monitoring and meticulous patient warming are needed in the perioperative period.

Casualties with spinal cord injuries quickly develop the potential for a hyperkalemic response to succinylcholine administration. The rapid increase in serum potassium that occurs can cause fatal dysrhythmias. The dramatic potassium release results from a rapid increase in the neural receptors on the muscle membranes when normal neural tone is interrupted by spinal cord injury. Succinylcholine should be avoided in patients with spinal cord injuries more than a few hours old.

Casualties with cervical cord injuries can also develop respiratory dysfunction. Forced vital capacity is greatly reduced in patients with lower cervical cord injuries because of loss of intercostal and abdominal muscle function. Aspiration and pneumonia are common complications. Careful pulmonary care is required in these patients to minimize serious respiratory complications.

During surgical stabilization of cervical spine injuries, the anesthesia provider can contribute to the improved outcome of patients by providing evoked-potential monitoring. Extension of spinal cord injury can be prevented in some cases with this neurological monitor.[16]

ASSOCIATED INJURIES

Injuries to the face and neck are frequently dramatic in appearance. They can divert the medical team's attention away from other associated injuries. The associated injuries, although they are at times less obvious than face and neck injuries, can nonetheless be serious and potentially life threatening, and can greatly affect patient outcome and anesthetic management. Once the airway is secure and the cervical spine is stabilized, the most serious of the injuries must be dealt with.

The proximity of the face and neck to the major vessels and other important structures makes the possibility of serious associated injuries likely. The injuries most commonly seen in association with face and neck trauma are intracranial and ocular.

Neurological Injuries

Most patients with extensive facial injuries have associated neurological injuries.[1] Overt head trauma may be detected on initial observation and examination of the patient; however, serious intracranial injury can be present with only minimal external trauma. During the primary trauma survey, the patient's pupillary symmetry and response are assessed and the patient's level of consciousness is quickly evaluated.[4] The Glasgow coma scale is a convenient and accepted system for evaluating and documenting the patient's level of consciousness (also see Chapter 1, Combat Trauma Overview, Chapter 3, Airway Management, and Chapter 16, Neurological Injuries). If neurological abnormalities are detected on initial evaluation or if extensive face and neck injuries are present, then neurosurgical consultation should be obtained.[17] Examination by a neurosurgeon and skull radiographs, computed tomography, and nuclear magnetic imaging are indicated in most cases.[18] If sophisticated imaging systems are not readily available, which will be the case in most field environments, then management decisions will need to be based on clinical evaluation. The focus then will be on stabilization and transfer of the casualty to a medical treatment facility equipped for full neurosurgical evaluation and care.

Patients with head injury and an altered level of consciousness, especially those whose Glasgow coma scale score is lower than 9, are likely to have increased intracranial pressure. The presence of elevated intracranial pressure significantly influences the airway-management plan and the perioperative anesthetic management plan. Special monitoring is indicated in these patients. The use of intracranial pressure monitoring allows the military trauma anesthesiologist to monitor the effects of anesthetic interventions. The availability of continuous capnography permits precise control of blood carbon dioxide levels through adjustments in ventilatory support. Carbon dioxide levels directly affect intracranial blood flow, which, in turn, influences intracranial pressure. In the postoperative period, repeated neurological examinations as well as continued monitoring of intracranial pressure are of value. If postoperative mechanical ventilation is required, continued monitoring of exhaled carbon dioxide is important.

Ocular Injuries

Eye injuries are common in the military combat environment. There are many causes, but eye injuries in combat most commonly are the result of fragmentation blasts from artillery, mortars, or other munitions. Proper anesthetic management of the patient with eye injuries is critical: mismanagement can lead to permanent disability (also see Chapter 17, Eye Injuries).

There are two basic types of eye injuries: penetrating (ie, *open*) and nonpenetrating. As a rule, nonpenetrating injuries are less severe than penetrating injuries, but either type can lead to blindness. Nonpenetrating eye injuries, in which the globe remains intact, usually present a lesser anesthetic-management dilemma than penetrating eye injuries, in which the globe is disrupted. Nonpenetrating eye injuries include injuries to the eye and orbit and can be as minor as a corneal abrasion or eyelid ecchymosis, or as severe as retinal detachment, vitreous hemorrhage, or optic nerve injury. Penetrating injuries can cause a wide spectrum of damage to the eye and orbital structures. Eye injuries in which the globe is fully perforated require careful anesthetic management to avoid extrusion of intraocular contents and resultant permanent disability.

In managing casualties with eye injuries, the anesthesia care provider must (*a*) avoid increased intraocular pressure and (*b*) provide a motionless surgical field for the ophthalmologist. Increased intraocular pressure in the open eye can lead to displacement of intraocular contents and permanent eye injury. Intraocular pressure can be increased by the patient's coughing and straining during attempts to manage the airway. Succinylcholine also increases intraocular pressure, caused by the contraction of extraocular muscles as well as other less-well-defined mechanisms.[19]

General anesthesia is usually required in ophthalmic trauma surgery. Retrobulbar block, while perfectly adequate for most routine ophthalmic surgery, is contraindicated in the presence of an open eye injury because it can increase intraocular pressure. The ideal general-anesthesia induction technique for a patient with a penetrating eye injury is similar to that for a patient with increased intracranial pressure. A technique should be chosen that will ensure that the patient is deeply anesthetized and fully paralyzed before the airway is instrumented. This will minimize the likelihood that intraocular pressure will be increased. Unless strongly indicated for other reasons (eg, immediate airway control), succinylcholine should be avoided and a nondepolarizing relaxant should be used in its place. Nondepolarizing relaxants do not increase intraocular pressure.[20] During the maintenance phase of the anesthetic, the patient should continue to remain deeply anesthetized and well paralyzed to avoid any movement of the eye or any increase in intraocular pressure during surgery. A smooth emergence from anesthesia will minimize the stress on delicate ophthalmic surgical repairs.

Other Injuries

Injuries to structures other than the cervical spine, eyes, and head or central nervous system can certainly be present in casualties with injuries to the face and neck (eg, thoracic, intraabdominal, pelvic, and orthopedic injuries). The presence of multiple associated injuries complicates management. Casualties with these kinds of injuries require evaluation by appropriate surgical specialists. The care plan must be individualized for each casualty and requires careful coordination among all the specialists involved.

AIRWAY MANAGEMENT

As with other medical emergencies, airway management of combat casualties is of prime importance. The airway requires immediate attention; additional resuscitative efforts are wasted if airway management is ineffective or delayed. Casualties with injuries to the face and neck may present with acute airway obstruction, or they may develop airway obstruction at some point during their care. The airway can be obstructed by blood, vomitus, broken teeth or bone fragments, disrupted soft tissue, or other foreign bodies. In addition, the posterior portion of the tongue may fall back and obstruct the airway.[21] This can occur as a result of the decreased muscle tone that can be seen in neurological injury, or it might be secondary to loss of support of the base of the tongue due to an unstable fracture of the mandible. Edema and hematomas in the airway can cause partial or complete airway obstruction. Laryngeal and tracheal injuries can distort and block the airway. Laryngeal injuries may be occult or otherwise appear minimal at the time of injury, but can progress to cause airway obstruction over time.[22] If tracheal disruption is present, positive-pressure ventilation may lead to subcutaneous and mediastinal emphysema, which can further distort the airway. Neck injuries can cause edema and hematomas, which can compress the airway.

Airway management of these casualties is often complicated by associated injuries that may be present. Cervical spine injury, intracranial injury, blood loss, and the risk of aspiration all influence the way that the airway is managed.

Mask Ventilation

Mask ventilation may be required in emergent circumstances to stabilize casualties who have face or neck injuries. The following conditions interfere with effective mask ventilation by causing an obstruction or otherwise preventing an effective mask seal:

- facial lacerations,
- nasal fractures,
- maxillary fractures,
- mandibular fractures, and
- dental trauma.

If the casualty's airway is obstructed by the tongue, then forward displacement of the mandible may open the airway. Pulling the tongue forward with gauze, clamps, or sutures are other maneuvers that may relieve obstruction of the airway. These techniques tend to interfere with mask ventilation, but if the casualty is making spontaneous respiratory effort, the relief of obstruction may be all that is needed to restore adequate ventilation. (Placing the casualty in a lateral position may also correct the obstruction, but such movement could potentially injure the cervical spinal cord if the cervical spine is unstable.) In many cases, placing an oral airway device will relieve the obstruction, but blind placement in a casualty with potential intraoral or pharyngeal injury could be harmful and could potentially worsen the obstruction.

Mask ventilation should be considered a temporary technique to stabilize the casualty while provisions are made to obtain more definitive airway control. During mask ventilation, the patient's airway remains unprotected and aspiration is always a risk. Blood and food in the stomach, bleeding in the airway, and an altered level of consciousness are factors that are frequently present and that increase the likelihood of aspiration.

Cricoid pressure in the casualty whose protective airway reflexes are inadequate will normally prevent passive regurgitation. However, attempts to block active vomiting with cricoid pressure are likely to fail and may cause esophageal injury. Proper positioning of the casualty and rapid, effective suctioning are the best means of dealing with active vomiting. If the casualty can cooperate, or if he has a nasogastric or orogastric tube in place, then a clear antacid solution can be given to neutralize the stomach acid. Reducing the acidity of stomach contents will decrease the pulmonary inflammatory response if aspiration does occur.

Tracheal Intubation

Tracheal intubation of casualties with face or neck injuries can be difficult. The possibility of cervical spine instability in these patients further complicates airway management. Intubation alternatives for casualties with possible cervical spine injuries include the following:

- orotracheal intubation with cervical immobilization,
- blind nasotracheal intubation,
- fiberoptic tracheal intubation,
- lighted stylet orotracheal intubation, and
- retrograde wire tracheal intubation.

Orotracheal intubation under direct laryngoscopic visualization is a technique with which anesthesia providers are quite comfortable. Direct visualization of the airway is valuable in patients with facial injuries because airway injuries can be assessed. In addition, the risk of esophageal intubation is reduced. Intubation under direct laryngoscopic visualization can be dangerous in patients with cervical spine injuries if the neck is manipulated. Some authorities[23] believe that orotracheal intubation of patients with cervical spine injuries could damage the spinal cord. Others[24,25] are confident that, with meticulous cervical spine immobilization, orotracheal intubation is safe and reliable. Cervical collars do not provide adequate stabilization for oral intubation.[26] The recommended technique for immobilization of the cervical spine is to have a skilled practitioner apply moderate, manual, in-line traction and stabilization to the head and cervical spine.[27] Preferably, the surgeon in charge should provide the in-line traction.[4] If that is not feasible, another appropriately trained member of the trauma team may apply the traction. The neck should be maintained in a neutral position throughout the intubation. If orotracheal intubation in a casualty with a potential cervical spine injury requires that the neck be extended, then an alternative airway-management technique should be selected.

Some authorities[28] believe that blind nasotracheal intubation should be the primary initial intubation technique for patients with possible cervical spine injuries. Blind nasal intubation is a simple, rapid technique that is reasonably reliable. However, it is difficult to perform successfully in apneic patients, and it is contraindicated in patients with midface or basilar skull fractures.[29] Because this is a blind technique, it should not be used if the integrity of the airway has been disrupted. False placement into a tissue plane may cause airway obstruction. If nasal intubation is required in a patient with midfacial or nasal injuries, the nasal airway should be inspected with a fiberscope prior to intubation. A common complication of blind nasal intubation is epistaxis. Blood in the airway complicates subsequent attempts at airway management.

Fiberoptic tracheal intubation is an excellent technique for securing the airway in casualties with potential cervical spine injuries or with facial injuries.[30] The neck is maintained in a neutral position and the airway is visualized throughout the intubation. The nasal or the oral route can be used. The technique is quick and reliable in skilled hands. In casualties with face and neck trauma, the fiberoptic technique allows the anesthesia provider to evaluate the integrity of the airway. Drawbacks include equipment expense, impairment by blood and secretions, the length of setup time required, and the need for training and experience. For these reasons, fiberoptic intubation is used primarily in the controlled, as opposed to the emergent, setting.

Retrograde wire tracheal intubation is useful in some patients with facial or possible cervical spine injuries.[31] A catheter is placed percutaneously through the cricothyroid membrane, angling cephalad. A flexible guide wire is inserted through the catheter and advanced until it can be pulled out of the mouth. A tracheal tube exchanger, or a substitute such as a section of a nasogastric tube, is threaded over the wire and into the mouth. An endotracheal tube is then inserted over the tube exchanger. The wire is pulled out from the mouth end and the endotracheal tube is advanced off the tube exchanger and down the trachea. A variation of this technique is to use a long guide wire and thread it through the suction port of a fiberoptic bronchoscope.[32] The bronchoscope is advanced blindly over the guide wire and is directed by the guide wire into the trachea. The wire is then removed and the bronchoscope is advanced to the carina. The endotracheal tube that was placed over the fiberoptic bundle is then advanced into the airway. The retrograde wire technique is quick and reliable. Its primary advantage is that it can be performed even if the airway contains blood or secretions.

Lighted stylet tracheal intubation is quick and reliable in skilled hands,[33] although this is a blind technique and should not be used in casualties who may have airway injuries. The casualty's neck is maintained in a neutral position during the intubation. The technique involves placing the endotracheal tube over a malleable lighted stylet. The stylet is bent to approximately a right angle at the level of the endotracheal tube cuff. The casualty's tongue or mandible is displaced forward and the stylet is directed blindly toward the glottis. The anesthesia provider observes the neck and watches for a bright, midline transillumination at the level of the lower portion of the thyroid cartilage. The endotracheal tube is then advanced off the stylet and down the trachea. The success rate for lighted stylet intubation is related to the experience and training of the practitioner.

Tracheal intubation of the unconscious patient can generally be accomplished without any anesthetic agents. Intubation of the conscious patient will normally require some form of topical or general anesthesia. Topical anesthesia puts the patient at risk for aspiration of gastric contents. If topical anesthesia is incomplete, airway stimulation during intubation may induce vomiting or may cause the patient to move suddenly. Induction of general anesthesia also abolishes protective airway reflexes and can cause severe hemodynamic instability in casualties who are hypovolemic from blood loss. The anesthesia provider must select the technique that provides the best balance between the intubating conditions and the patient's stability. The subject is discussed in greater detail in Chapter 3, Airway Management.

Transtracheal Jet Ventilation

Transtracheal jet ventilation is a temporizing technique that stabilizes the patient and allows time for the practitioner to secure longer-term control of the airway. The technique involves placing a large intravenous catheter, such as a 14-gauge catheter, percutaneously through the neck into the upper trachea. This is connected to a high-pressure oxygen source (50 psi) with a tubing system that has an adjustable pressure regulator and a manual valve. The oxygen source can be a wall source, an oxygen tank, or the flush-valve output of the anesthesia machine. The breathing circuit of the anesthesia machine is not an acceptable gas source for transtracheal jet ventilation because the driving pressure is too low. Bag-valve systems are unacceptable for the same reason. The specific components that make up an effective transtracheal jet ventilation system are well described in the literature.[34] To be useful in emergencies, the system must available and already connected to an oxygen source.

The anesthesia provider provides manual ventilation for the patient, while also adjusting the driving pressure and watching the patient's chest rise and fall with each breath. The advantages of transtracheal jet ventilation are that it is fast, effective, and lifesaving. The disadvantages are the risk of bleeding from catheter placement, and the risk of pneumothorax if the driving pressure is too high or if the tracheal outlet is obstructed. Improper placement of the catheter may lead to subcutaneous emphysema. Inadequate alveolar ventilation will result in hypercarbia.

Cricothyroidotomy

In some casualties with face or neck injuries, adequate mask ventilation may be impossible, and tracheal intubation may be dangerous or unsuccessful. In the emergent situation, cricothyroidotomy is a rapid and effective means of airway control. Since cricothyroidotomy has a significant complication rate in the emergency setting,[35] it should be performed only when the airway cannot be secured by other methods.

If the anatomical landmarks are not distorted, a cricothyroidotomy incision can quickly be made between the thyroid cartilage and the cricoid cartilage. A small, cuffed endotracheal tube, or any makeshift stent, can be placed through the incision into the airway.

Most anesthesia providers prefer cricothyroidotomy to tracheostomy in emergent situations because

- the risk of bleeding is reduced,
- surgical access is quicker, and
- anatomical landmarks are more reliable.

Tracheostomy

Tracheostomy may be performed as the initial airway-management technique in selected casualties with face and neck injuries. If the casualty has (*a*) severe facial injuries that preclude safe or successful orotracheal or nasotracheal intubation and (*b*) injury to the cricothyroid region of the neck that distorts the anatomical landmarks, then emergent tracheostomy may be the best option. Tracheostomy may also be required if the cricothyroid region of the airway or the uppermost portion of the trachea is disrupted. In these cases, tracheostomy allows access to the airway below the area of injury. In some patients with specific combinations of facial fractures, tracheostomy may be required so that the surgery can be completed. If time allows and the patient is stable, awake tracheostomy at the beginning of the surgery may be safer than the anesthesia provider's attempting to perform orotracheal or nasotracheal intubation in the presence of multiple facial fractures and a potentially unstable cervical spine. In most cases where postoperative tracheostomy will be necessary, however, it is best to wait until near the conclusion of the surgery to perform the tracheostomy.

PERIOPERATIVE ANESTHETIC MANAGEMENT

In the management of patients with face and neck trauma, airway stabilization takes top priority. Other problems that require early attention (and are often a result of associated injuries) are hemorrhage and hypovolemic shock. Stabilization of these patients requires early and continued involvement of the anesthesia team, as well as the coordinated efforts of multiple surgical specialty teams when associated injuries are present.[18] Although the dramatic appearance of face and neck injuries may divert the attention of the medical personnel away from the casualty's other injuries, expedient care of the associated injuries may initially take precedence over repair of the face and neck injuries. The individual surgical teams may have distorted views of the priorities of medical care, and communication among the surgical teams—including the anesthesia team—is crucial to assure that proper priorities are maintained and that care proceeds appropriately. The anesthesia team must seek active involvement in the preparation and planning for surgery to ensure that the associated injuries are identified preoperatively, and that the patient is maximally resuscitated and stabilized preoperatively.

Numerous associated problems that can complicate perioperative anesthetic management may be present in patients with face and neck trauma:

- an inadequate airway,
- hemorrhage,
- intracranial injury,
- spinal injury,
- pulmonary contusion,
- pulmonary aspiration,
- pneumothorax,
- cardiac contusion,
- cardiac tamponade,
- intraabdominal injury, and
- renal injury.

Some problems, such as pneumothorax, cardiac tamponade, and external hemorrhage, should be corrected before the administration of general anesthesia, if at all possible. Other problems, such as intraabdominal injury, can be stabilized under general anesthesia, whereas problems like increased intracranial pressure, aspiration pneumonitis, and acute renal failure will have a significant impact on anesthetic management and will continue to require attention throughout the perioperative period. Safe anesthetic management depends on the ability to monitor affected organ systems during the resuscitative and operative phases of treatment.[18] Physiological monitoring of the patient with face and neck trauma may include such modalities as central venous lines, arterial lines, Foley catheters, repeated blood analysis, and possibly intracranial pressure monitoring, in addition to the usual anesthesia monitoring. Appropriate perioperative anesthesia monitoring may help identify ongoing renal, respiratory, and neurological injury.

Local and Regional Anesthesia

Not all face and neck trauma patients require general anesthesia. Patients with multiple injuries and patients with severe maxillofacial injuries will normally require general anesthesia, but patients with isolated and less-severe injuries may do well with regional and local anesthesia. Limited facial soft-tissue injuries can usually be repaired with local anesthesia alone. In fact, the use of epinephrine-containing local anesthetic will provide improved hemostasis compared with that provided by regional or general anesthesia. Local and regional anesthesia, however, can induce temporary paralysis of the facial nerve, which may interfere with the diagnosis of facial nerve injury. Regional anesthesia can be used for selected areas of the face and neck.

General Anesthesia

Patients who require extensive or lengthy procedures and patients who are uncooperative will need general anesthesia.[36] Anesthetic techniques and monitoring are influenced primarily by the associated injuries that are present. Anesthetic induction and intubation require careful evaluation of the airway and consideration of the side effects of the induction agents. Anesthetic induction is greatly simplified if the casualty's airway was intubated during the initial stabilization and resuscitation. Induction agents can then be selected and titrated to produce minimal adverse effects on the associated injured organ systems. If intubation is required in the operating room, then induction agents and techniques must be selected that provide maximally safe intubating conditions while at the same time minimize risk to injured organ systems. All factors must be considered, and each situation must be individualized.

The safest induction technique for patients at risk for aspiration, which includes most trauma victims, is usually a rapid-sequence induction using a hypnotic agent such as ketamine or sodium thiopental along with succinylcholine. However, in patients with possible cervical spine injury, which, again, includes many trauma patients, awake intubation with cervical spine immobilization is generally indicated, if time and conditions allow. Patients with increased intracranial pressure and patients with open eye injuries should have a slow, controlled, and complete induction of anesthesia with sodium thiopental or a similar hypnotic agent, a narcotic agent, and a nondepolarizing muscle relaxant prior to intubation of the airway. This technique minimizes the likelihood of a dangerous increase in intracranial pressure or intraocular pressure at the start of anesthesia.

Patients with severe hypovolemia from acute blood loss may not tolerate standard anesthetic-induction techniques. Severe hypotension or cardiac arrest may occur if the patient is given a hypnotic induction such as ketamine, which causes cardiac depression, or sodium thiopental, which causes sympathetic and cardiac depression. The safest induction technique for these patients will generally be scopolamine and a muscle relaxant alone.

No single induction technique is suitable for all trauma situations. Often, the medical officer will be confronted with a combination of injuries and conditions that make choosing the best anesthetic-induction technique difficult (eg, a patient with a head injury and a full stomach, a patient with an open eye injury and a displaced mandibular fracture, and an uncooperative patient with bleeding and possible cervical spine injury). In scenarios such as these, the anesthesia provider must first decide which conditions are of overriding importance and then select the most appropriate airway-management technique and anesthetic plan for those conditions. Careful clinical assessment is required for every case.

Intraoperative Airway Management

Completion of the initial intubation does not mean that the airway can then be ignored. Accidental extubation can easily occur when maxillofacial surgical procedures are in progress. It may be difficult to secure an orotracheal or nasotracheal tube in patients with facial injuries due to tissue disruption and surgical cleansing. Suturing the tracheal tube in place, monitoring the progress of surgery, communicating with the surgeons, assisting with head positioning, and continuously monitoring the patient's ventilation will all help to decrease the risk of accidental extubation.

Both the specific injuries and the specific surgical procedures planned have an impact on airway management. Orotracheal intubation is generally the preferred method for initial intubation, but some surgical procedures (ie, procedures requiring intermaxillary fixation) cannot be completed with an orotracheal tube in place. If intermaxillary fixation is required, then orotracheal intubation must be converted either to a nasotracheal placement or to a tracheostomy. Nasotracheal intubation is acceptable in patients who do not have nasal fractures, but if nasal fractures are present in conjunction with other fractures necessitating intermaxillary wiring, then a tracheostomy is likely to be needed. Tracheostomy in casualties with face and neck injuries is indicated[18] in patients

- who have significant intracranial injuries that require intermaxillary fixation;
- who have nasal fractures combined with maxillary or mandibular fractures that require intermaxillary fixation;
- who have significant pulmonary injuries or flail chest, and who also require intermaxillary fixation;
- whose massive soft-tissue swelling may interfere with reintubation;
- who were intubated emergently via a cricothyroidotomy; and
- who have injuries to the laryngeal or cricothyroid region.

The placement of a tracheostomy tube does not guarantee that the airway is secure. The tracheostomy tube can easily become dislodged and, if the tracheostomy was recently performed, emergent replacement of the tracheostomy tube may cause the tube tip to be placed into a blind tract between tissue planes. Placing "stay" sutures during the tracheostomy procedure will aid in (*a*) identifying the appropriate tissue planes and (*b*) replacing the tracheostomy tube if the tube becomes dislodged before the tracheostomy site has healed. An armored tube, sutured in place, may be more secure intraoperatively than a standard tracheostomy tube.

Postoperative Airway Management

Patients who are emerging from anesthesia and are recovering from surgical repair of their face and neck injuries require special attention. If the patient is to be extubated at the conclusion of the surgical procedure, airway protection must be assured. Caution is required in the patient with intermaxillary wiring. Intact airway reflexes must be present, although that alone does not guarantee that aspiration will not occur. Aspiration in the presence of intermaxillary wiring can easily be fatal.[37] Attention must focus on reducing the risk of emesis and rapidly dealing with it when it occurs. Evacuating gastric contents with a suction tube and giving an antiemetic agent prior to extubation will help. Wire cutters must be immediately available at the bedside and the specific locations of the wires to be cut should be made clear to personnel caring for the patient.

Even if the jaws are not wired, other problems can occur with extubation. If significant soft-tissue trauma has occurred, postoperative edema or hematomas may lead to progressive airway obstruction after extubation. If the patient remains intubated postoperatively, accidental extubation in an uncontrolled environment can lead to disaster. Vigilance must be maintained throughout the perioperative period well into the recovery period in patients with face and neck injuries.

SUMMARY

Casualties with face and neck injuries present challenging problems to the anesthesiologist. Airway management can be complicated. Serious associated injuries, especially head injuries, are often present and can have a significant impact on anesthetic care. Initial management should follow published ATLS guidelines. Securing the airway, protecting the cervical spine, and providing ventilation and controlling hemorrhage as needed are the top priorities. Subsequent management must be carefully planned and prioritized. This requires the coordinated effort of the anesthesia team and the various surgical subspecialty teams involved.

REFERENCES

1. Grande CM, Wyman CI, Bernhard WN. Perioperative anesthetic management of maxillofacial and ocular trauma: Injuries of the craniofacial complex. In: Stene JK, Grande CM, eds. *Trauma Anesthesia*. Baltimore, Md: Williams & Wilkins; 1991: 266–285.

2. Bellamy RF. Unpublished analysis of the Wound Data and Munitions Effectiveness Team database. Personal communication, September 1993.

3. Bellamy RF, Zajtchuk R. The weapons of conventional land warfare. In: Bellamy RF, Zajtchuk R, eds. *Conventional Warfare: Ballistic, Blast, and Burn Injuries*. Part 1, Vol 5. In: Zajtchuk R, Jenkins DP, Bellamy RF, eds. *Textbook of Military Medicine*. Washington, DC: US Department of Army, Office of The Surgeon General, and Borden Institute; 1991: Chap 1.

4. Committee on Trauma, American College of Surgeons. *Advanced Trauma Life Support Program for Physicians: Instructor Manual.* 5th ed. Chicago, Ill: American College of Surgeons; 1993.

5. Le Fort R. Etude experimentale sur les fractures de la machoire superieure. *Rev Chir*. 1901;23:208–227.

6. McSwain NE. Penetrating neck wounds: Major advances in the 1980's. In: Maull KI, Cleveland HC, Strauch GO, Wolferth CC, eds. *Advances in Trauma*. Chicago, Ill: Yearbook Medical Publishers; 1986: 135–140.

7. Ordog GJ, Albin D, Wasserberger J, et al. 110 bullet wounds to the neck. *J Trauma*. 1985;25:238–241.

8. Capan LM, Miller SM, Turndorf H. Management of neck injuries. In: Capan LM, Miller SM, Turndorf H, eds. *Trauma Anesthesia and Intensive Care*. Philadelphia, Pa: JB Lippincott; 1991: 409–446.

9. Ayuyao AM, Kaledzi YL, Parsa MH, Freeman HP. Penetrating neck wounds: Mandatory versus selective exploration. *Ann Surg*. 1985;202:563–566.

10. Richardson JD, Martin LF, Borzotta AP, Polk HC. Unifying concepts in treatment of esophageal leaks. *Am J Surg*. 1985;149:157–160.

11. Kreipke DL, Gillespie KR, McCarthy MC, Mail JT, Lappas JC, Broadie TA. Reliability of indications for cervical spine films in trauma patients. *J Trauma*. 1989;29:1438–1439.

12. Guthkelch AN, Fleischer A. Patterns of cervical spine injury and their associated lesions. *West J Med*. 1987;147:428–431.

13. Kellman R. The cervical spine in maxillofacial trauma. *Otolaryngol Clin North Am*. 1991;24:1–13.

14. Hastings RH, Marks JD. Airway management for trauma patients with potential cervical spine injuries. *Anesth Analg*. 1991;73:471–482.

15. Bracken MB, Shepard MJ, Collins WF, et al. Second National Acute Spinal Cord Injury Study. A randomized, controlled trial of methylprednisolone or naloxone in the treatment of acute spinal cord injury. *N Engl J Med*. 1990;322:1405–1411.

16. Rose DD, O'Hara CA, Fossum SR, Hanowell LH. Cervical spine injury: Perioperative patient care. *AORN J*. 1993;57:830–850.

17. Martin SH. Injury of the head and cervical spine. *Otolaryngol Clin North Am*. 1976;9:403–423.

18. Manson PN, Saunders JR. Anesthesia in head and neck surgery: Head and neck cancer surgery and maxillofacial trauma. *Clin Plast Surg.* 1985;12:115–122.

19. Wislicki L, Factors affecting intraocular pressure. *Proc R Soc Med*. 1977;70:372–374.

20. Calobrisi B, Lebowitz P. Muscle relaxants and the open globe. *Int Anesthesiol Clin*. 1990;28:83–85.

21. Strate RG, Boies LR. The emergency management of trauma. *Otolaryngol Clin North Am*. 1976;9:315–330.

22. Huff JS, Magielski JE. Surgical treatment of laryngeal injuries. *Otolaryngol Clin North Am*. 1976;9:393–401.

23. Bivins HG, Ford S, Bezmalinovic Z. The effect of axial traction during orotracheal intubation of the trauma victim with an unstable cervical spine. *Ann Emerg Med*. 1988;17:25–29.

24. Scannell G, Waxman K, Tominaga G, Barker S, Annas C. Orotracheal intubation in trauma patients with cervical fractures. *Arch Surg*. 1993;128:903–906.

25. Walls RN. Airway management. *Emerg Med Clin North Am*. 1993;11:53–60.

26. Aprahamian C, Thompson BM, Finger WA, et al. Experimental cervical spine injury model: Evaluation of airway management and splinting techniques. *Ann Emerg Med*. 1984;13:584–587.

27. Wood PR, Lawler PG. Managing the airway in cervical spine injury: A review of the advanced trauma life support protocol. *Anaesthesia*. 1992;47:792–797.

28. Jorden RC, Rosen P. Airway management in the acutely injured. In: Moore EE, Eisman B, VanWay EW, eds. *Critical Decision in Trauma*. St. Louis, Mo: CV Mosby; 1984: 30–35.

29. Rosenbaum P. Anesthesia for eye, head, and neck surgery. In: Firestone LL, Lebowitz PW, Cook CE, eds. *Clinical Anesthesia Procedures of the Massachusetts General Hospital*. Boston, Mass: Little, Brown; 1988: 346–365.

30. Ovassapian A, Dykes MH. The role of fiberoptic endoscopy for airway management. *Semin Anesth*. 1987;6:93–104.

31. Barriot P, Riou B. Retrograde technique for tracheal intubation in trauma patients. *Crit Care Med*. 1988;16:712–713.

32. Gupta B, McDonald JS, Brooks JH, Mendenhall J. Oral fiberoptic intubation over a retrograde wire. *Anesth Analg*. 1989;68:517–519.

33. Ellis DG, Stewart RD, Kaplan RM, et al. Success rates of blind orotracheal intubation using a transillumination technique with a lighted stylet. *Ann Emerg Med*. 1986;15:138–142.

34. Benumof JL, Scheller MS. The importance of transtracheal ventilation in the management of the difficult airway. *Anesthesiology*. 1989;71:769–778.

35. McGill J, Clinton JE, Ruiz E. Cricothyrotomy in the emergency department. *Ann Emerg Med*. 1982;11:361–364.

36. Dickinson JT, Jaquiss GW, Thompson JN. Soft tissue trauma. *Otolaryngol Clin North Am*. 1976;9:331–360.

37. Sims J, Giesecke AH. Airway management. In: Giesecke AH, ed. *Anesthesia for the Surgery of Trauma.* Philadelphia, Pa: FA Davis; 1976: 71–78.