

Chapter 21

Fractures of the Upper Thoracic Spine: Approaches and Surgical Management

Sean D Christie, M.D., John Song, M.D., and Richard G Fessler, M.D., Ph.D.

INTRODUCTION

Fractures occurring in the thoracic region account for approximately 17 to 23% of all traumatic spinal fractures (1), with 22% of traumatic spinal fractures occurring between T1 and T4 (16). More than half of these fractures result in neurological injury, and almost three-quarters of those impaired suffer from complete paralysis.

Obtaining surgical access to the anterior vertebral elements of the upper thoracic vertebrae (T1–T6) presents a unique anatomic challenge. The thoracic cage, which narrows significantly as it approaches the thoracic inlet, has an intimate association between the vertebral column and the superior mediastinal structures. The supraclavicular, transmanubrial, transthoracic, and lateral parascapular extrapleural approaches each provide access to the anterior vertebral elements of the upper thoracic vertebrae. However, each of these approaches has distinct advantages and disadvantages and their use should be tailored to each individual patient's situation. This chapter reviews these surgical approaches. Traditional posterior approaches are illustrated in Figure 21.1, but will not be discussed in depth here.

ANATOMIC CONSIDERATIONS AND STABILITY

The upper thoracic spine possesses unique anatomic and biomechanical properties. The anterior aspects of the vertebral bodies are smaller than the posterior aspects, which contribute to the physiological kyphosis present in this region of the spine. Furthermore, this orientation results in a ventrally positioned axis of rotation, predisposing this region to compression injuries. The combination and interaction of the vertebral bodies, ribs, and sternum increase the inherent biomechanical stability of this segment of the spine to 2 to 3 times that of the thoracolumbar junction. The costovertebral joints play an important role in this stability, forming a bony cylindrical shell (1, 15) that increases the rigidity of the upper thoracic spine. The enhanced stability in this region requires that greater forces be applied to the spine to generate significant fractures. Therefore, fracture–dislocations occur less commonly in the upper thoracic spine; however, they are more likely to result in complete neurological injury because the size of the spinal cord approximates that of the spinal canal, and because this region of the spinal cord is thought to have a tenuous blood supply (6).

SURGICAL CHALLENGES AND GOALS OF TREATMENT

The unique anatomic relationships also create challenges for the surgeon approaching the upper thoracic spine. Other anatomic factors affecting surgical approaches include the narrow thoracic inlet, the contents of the mediastinum, the lungs, and the limitations related to the shoulder and scapular musculature. The nature of the fracture also plays a role in dictating the approach. Figures 21.2 and 21.3 outline a treatment algorithm for compression and burst fractures, respectively. Furthermore, one must be attentive to the goals of the procedure: to decompress the spinal cord, to realign and stabilize the spine, and to maximize physical function. These factors must

be considered when tailoring a surgical approach to an individual patient.

SUPRACLAVICULAR APPROACH

Brunig (4) and Jonnesco (10) independently described this approach in 1923, which initially found favor in the treatment of spastic paralysis (13), Raynaud's Disease (8), and thoracic sympathectomy (12).

After adequate general endotracheal anesthesia, a transverse skin incision is made, approximately 2 cm above the clavicle, extending from the midline past the lateral border of the sternocleidomastoid (SCM) muscle. We use a left-sided approach to minimize the risk of injuring the recurrent laryngeal nerve. The superficial fascia and the platysma muscle are divided and undermined. The anterior and external jugular veins may be ligated and cut for exposure. The superficial layer of the deep cervical fascia is then opened along the anterior border of SCM. The SCM is isolated and transected, reflecting both heads rostrally. The medial third of the clavicle is cut and disarticulated from the manubrium, while preserving the subclavian vein. The omohyoid and sternohyoid muscles must be divided to reveal the anterior scalene muscle along with the associated phrenic nerve. The carotid artery is then palpated and retracted laterally. The standard cervical anatomic plane, between the trachea and esophagus medially and the carotid sheath laterally, is opened. Care must be taken to protect the recurrent laryngeal nerve, in the tracheo-esophageal groove; the phrenic nerve, along the anterior aspect of the anterior scalene muscle; and the thoracic duct, located laterally at the junction of the internal jugular and subclavian veins. After adequate exposure has been obtained, the prevertebral fascia is opened in the midline, and the anatomic level may be confirmed radiologically with the use of a 25-gauge needle. Dissecting and elevating the longus colli muscles enables the placement of retractors to complete the exposure. The operating microscope may then be brought in to facilitate decompression, if needed, before instrumentation.

At the end of the case, the retractors are removed and the wound is irrigated copiously with Bacitracin solution. A Jackson-Pratt drain may be left in place if there is any doubt regarding hemostasis. The strap muscles are reapproximated and the SCM is sutured back to the clavicular periosteum. The platysma and skin are closed in separate layers. If necessary, an external orthosis may be applied.

TRANSMANUBRIAL APPROACH

The addition of a transmanubrial or sternal splitting approach to the transclavicular will enhance the exposure to the cervicothoracic junction and the upper thoracic vertebrae. This approach was initially described by Sundaresan et al. in 1984 (14) and then later modified by Birch et al. in 1990 (2).

After induction of general endotracheal anesthesia and sterile draping, a T-shaped incision is fashioned, as illustrated in Figure 21.4, with the horizontal limb 1 to 2 cm above the clavicle. The vertical limb of the incision extends halfway down the sternum. The superficial dissection is the same as described above.

The left SCM is identified and its muscular heads dissected from their osseous attachments and reflected superiorly and laterally (Fig. 21.5). The ipsilateral strap muscles are also identified and sectioned as described above. The suprasternal space of Burns is developed via blunt dissection. This facilitates the subperiosteal dissection of the manubrium and the medial third of the clavicle. The omohyoid muscle is then divided to reveal the carotid sheath and

its contents. Caution is warranted to preserve the periosteum and the anterior aspect of the transthoracic fascia to prevent injury to the underlying innominate vessels and mediastinal structures.

The medial third of the clavicle is removed using a high-speed drill or the Gigli saw, and the first costal cartilage is divided. The section of clavicle can then be disarticulated and removed. The high-speed drill is used to resect a rectangular portion of the manubrium. Alternatively, if an adequate subperiosteal dissection has been achieved beneath the manubrium and clavicle, these structures may be removed en bloc, with or without the SCM attachments (Fig. 21.6).

The underlying vascular structures are identified and small venous tributaries of the innominate vein can be doubly ligated and sectioned. The thymus and any additional fat present in the superior mediastinum can be mobilized or resected. Working from the cephalad end of the exposure, the cervical fascia is opened as described above to reveal the prevertebral fascia. Attention must be paid to the numerous critical anatomic structures located in this region, particularly the carotid arteries, internal jugular vein, vagus nerve, subclavian artery, trachea, esophagus, the left recurrent laryngeal nerve, the thoracic duct, the thyrocervical trunk, the phrenic nerve, and the aortic arch and its branches, which limit the caudal exposure to approximately the level of the T3 vertebral body.

After the prevertebral fascia is opened, the ventral aspect of the spine is identified and anatomic levels are confirmed with radiography or fluoroscopy. The longus colli muscles are dissected and elevated to facilitate placement of handheld or self-retaining retractors. At this point, the operating microscope may be brought into the field as necessary to aid in any decompression and realignment. After stabilization, the wound is irrigated copiously with Bacitracin irrigation. Should the pleura be violated, a chest tube is inserted through a separate stab wound and placed to suction or underwater seal. The manubrium and clavicle are replaced and fixed with mini-plates or stainless steel wires. The remainder of the closure proceeds as described above. When necessary, appropriate external immobilization is placed before extubation.

Chapter 21, Fractures of the Upper Thoracic Spine: Approaches and Surgical Management (continued)

TRANSTHORACIC APPROACH

In detailing the management of a cohort of patients with Pott's disease, Hodgson et al. (9) were the first to describe the thoracotomy approach to the ventral spinal column.

The spine may be either approached from the right or left side. Although the left side is generally favored for lesions in the lower thoracic spine and the thoracolumbar junction, a right-sided approach is often used for the upper thoracic spine because of the location of the great vessels.

The patient is placed in the lateral decubitus position (Fig. 21.7). It is important to maintain the patient's orientation, keeping in mind the 3-D orientation of the spine. An axillary roll is placed to minimize the risk of brachial plexus injury. Fluoroscopy is used to confirm and mark the skin incision. The incision is made over the rib, one or two levels above the pathological vertebrae. A subperiosteal dissection is performed, protecting the inferior neurovascular bundle. The rib is then removed and the rib spreader is placed.

Either a retropleural or a transpleural approach to the spine may be used. The retropleural approach requires blunt dissection to mobilize the pleura off the posterior chest wall and vertebral bodies. This exposes the sympathetic chain, radicular vessels, rib, and the vertebral bodies. If the pleura is not violated, there is no need to place a chest tube at the conclusion of the case. The transpleural approach requires the lung to be retracted with a malleable or "egg-beater" retractor so that the spine can be visualized through the parietal pleura. This section of pleura must be incised and reflected back, thereby exposing the spine. Closure requires re-approximation of the parietal pleura and placement of a chest tube.

Segmental vessels in the area of planned resection are removed early to minimize blood loss during the remainder of the procedure. The vessels are ligated close to the vertebral body to maintain the anastomoses more distally and minimize the risk of ischemic insult to the spinal cord.

The proximal 2 to 3 cm of the head of the rib is sectioned using a high-speed drill or osteotome, and disarticulated. This reveals the intercostal nerve, which is an important landmark for the neural foramen and the pedicle. Identification of these structures facilitates an appreciation of the location of the thecal sac. Early identification of the thecal sac is imperative for safe resection of ventral pathology. The discs above and below the pathological vertebrae are incised and removal is in an anterior direction, away from the thecal sac. A high-speed drill with a cutting burr is used to remove the majority of the ventral aspect of the vertebral body. The anterior cortex and anterior longitudinal ligament are left intact, if possible. The posterior cortical margin is thinned down to an egg-shell thickness, and then can be fractured into the cavity created using curettes, thereby decompressing the spinal cord. An adequate decompression from pedicle to pedicle should be confirmed before beginning reconstruction.

As noted, violation of the parietal pleura requires primary closure and placement of a chest tube. For the retropleural approach, the wound should be filled with saline to confirm that there are no occult leaks. Individual muscles are identified and closed in layers with either interrupted or running sutures. Early chest x-ray in the recovery room is warranted to exclude pneumothorax.

LATERAL PARASCAPULAR EXTRAPLEURAL APPROACH

The lateral parascapular extrapleural approach was first described in 1991 (7) as a modification of Capener's lateral rhachotomy approach (5) and the lateral extracavitary approach of Larson et al. (11), to deal with the limitations imposed by the shoulder girdle when these earlier approaches were used to approach the cervicothoracic junction.

After induction of general, endotracheal anesthesia, the patient is placed in a prone position on the operating table with appropriate chest and hip padding. It is important to use a bed that allows free movement of the fluoroscope, not only in the region of interest but also either higher or lower to allow counting of vertebral bodies for localization. The arms can either be tucked at the patient's side or positioned abducted away from the body. By abducting the arm, the scapula is rotated forward and away from the midline spine, thus, providing more room for retraction of the paraspinal musculature.

The incision must extend from three to four levels above the lesion to three to four levels below the lesion (Fig. 21.8). However, because of the relative tethering effect of the trapezius and levator scapulae muscles, a lesion located at T1 or T2 will require an incision that extends all the way up to approximately C3 or C4. Note that in the prone

position, before takedown of the trapezius and rhomboid musculature, the scapula covers the lateral one-half of the posterior rib cage. This position makes mobilization of the trapezius and rhomboid musculature imperative to exposure of the upper thoracic spine.

In the initial dissection for exposure of this region of the spine, the spinous process insertions of the trapezius, rhomboid, serratus posterior superior, splenius capitis, and splenius cervicis muscles are taken down, as a group, for lateral retraction (Fig. 21.9). As these muscles are taken down, the scapula is released from its attachments to the spinous processes and rotates anterolaterally out of the operative field. This exposes the posterior and posterolateral rib cage for the remainder of the procedure. During this rotation, all neurovascular structures rotate with the scapula and are not at risk of injury. The entire group of erector spinae muscles and transversospinalis muscles can be dissected off the spinous processes, laminae, facets, and transverse processes as a single muscular mass (Fig. 21.10). The insertions of the iliocostalis thoracis muscles are also taken down. Control of the musculature in this way exposes all of the vertebral elements from the tip of the spinous processes to the tip of the transverse processes, as well as the costotransverse ligaments, the joints, and the ribs.

After blunt dissection to remove the intercostal muscles and the costotransverse and radiate ligaments, each rib can be resected. This resection should extend 6 to 8 cm lateral to the junction of the rib with the transverse process. In the course of this procedure, a strip of intercostal musculature is isolated between each rib. This strip of musculature will contain the intercostal nerve, artery, and vein as they pass laterally between the internal intercostal membrane and the pleura, and then between the internal and innermost intercostal muscles. Immediately ventral to the intercostal bundle and the intercostal muscles lays the pleura. With blunt dissection, the pleura can be separated from these structures to expose the lateral vertebral elements.

Following the intercostal bundle medially will enable identification of the neural foramen. Within the neural foramen, the dorsal root ganglion can be identified along with the gray and white rami communicantes, which course ventrally to the sympathetic chain and ganglia. The sympathetic chain is contained within a fascial compartment over the costovertebral articulation. This compartment is formed by fusion of the mediastinal and prevertebral fascia.

The major portion of the ventral ramus of the first thoracic nerve passes cephalad across the neck of the first rib to join the C8 nerve in the brachial plexus. A small intercostal branch runs across the inferior surface of the first rib to enter the first interspace close to the costal cartilage. The ventral ramus of the second thoracic nerve also usually sends a small branch to the brachial plexus. Occasionally, this branch will be very large, in which case, the lateral cutaneous branch of the second intercostal nerve is small or absent. Although the intercostal nerves below T1 can usually be sacrificed to facilitate exposure, the T1 and C7 intercostal nerves, which frequently are exposed during this procedure, cannot be sacrificed without causing a severe neurological deficit in hand function. Therefore, it is occasionally necessary to work around the inferior portion of the brachial plexus in this exposure.

The phrenic nerve is located in the groove between the trachea and the vena cava on the right, and draping over the aorta and pulmonary arch on the left. The right vagus nerve courses dorsally over the trachea, under the azygous vein, to run in the groove between the trachea and esophagus. The left vagus nerve courses over the aortic arch and under the pulmonary artery to assume a similar position on the left. The thoracic duct is found on the left posterolateral aspect of the esophagus, cephalad to the aorta.

With these anatomic relationships in mind, decompression can proceed in a manner similar to that described above for the transthoracic approach. Again, it is imperative to identify the landmarks to conceptualize the location of the thecal sac at all times. After decompression and reconstruction, the individual muscles are reapproximated in layers and the skin closed with a running suture or staples. Again, an early chest x-ray in recovery is warranted to exclude the possibility of pneumothorax.

MINIMALLY INVASIVE SURGICAL TECHNIQUE

The senior author has recently experimented with a variant of the lateral parascapular approach requiring a less extensive skin incision and muscle dissection/retraction. This is made possible by newer, tubular retractors designed specifically for spinal surgery. The technique requires an approximately 30-mm paramedian incision placed either vertically or horizontally (depending on extent of pathology and surgeon preference), centered both at the level of interest vertically and the costovertebral junction (or farther) laterally. Soft tissue dissection is carried down to expose the lamina, facet, and ribs. The rib of the involved level is dissected from the pleura and neurovascular bundle and removed. The bone is saved for autologous grafting. After the rib has been removed, the retractor system can be placed.

The remainder of the surgery can be carried out in standard fashion, albeit in a more confined surgical field. Anterior instrumentation can be successfully carried out by this method.

SUMMARY

Management of upper thoracic spinal fractures continues to be a challenging task for spinal surgeons. Appropriate treatment depends on a variety of factors, including the nature of the fracture, the need for neural decompression, and the need for spinal stabilization. A number of surgical approaches have been developed to address these lesions. Each approach carries its own inherent advantages and disadvantages and an understanding of each is required to optimize the treatment of any individual patient. As our surgical experience and expertise continues to grow in the field of minimally invasive surgery, these techniques and novel approaches will provide alternatives for our patients that will maintain the current quality of care but minimize surgical trauma and improve recovery times.

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Fig. 21.1 Diagrammatic representation of the standard posterior approaches to the upper thoracic spine.

Fig. 21.2 Treatment algorithm for compression fractures of the upper thoracic spine.

Fig. 21.3 Treatment algorithm for burst fractures of the upper thoracic spine.

Fig. 21.4 Illustration of the T-shaped incision used in the transmanubrial approach.

Fig. 21.5 Illustration depicting the reflection of the sternocleidomastoid and strap muscles during the transmanubrial approach. Note the clavicular cut being performed with a Gigli saw.

Fig. 21.6 Illustration of the ultimate spinal exposure after a transmanubrial approach.

Fig. 21.7 Patient positioning and incision placement for the transthoracic approach.

Fig. 21.8 External landmarks and incision placement for the lateral parascapular extrapleural approach.

Fig. 21.9 Operative and diagrammatic representation of the initial myocutaneous flap that enables anterolateral scapular rotation.

Fig. 21.10 Intraoperative photograph and illustration depicting the exposure of the ribs and posterior vertebral elements after elevation of the erector spinae complex.