Anterior approach to the cervicothoracic junction: proposed indication for manubriotomy based on preoperative computed tomography findings

Clinical article

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Object. The purpose of this study was to present straightforward preoperative methods to define the need for manubriotomy in the anterior surgical approach to the cervicothoracic junction.

Methods. Preoperative MR imaging and CT scanning studies were performed in all patients. The CT images with sagittal reconstructions including the manubrium were done to apply the so-called surgeons’ view line. This line is parallel to the inferior plateau of the superior healthy vertebrae or the vertebrae above the herniated intervertebral disc, and the decision concerning the need for manubriotomy depends on the correlation between this line and the manubrium.

Results. Preoperative planning of the need for manubriotomy was correct in all cases. Manubriotomy was never performed in C-7 corpectomy or C7–T1 discectomy cases; nevertheless, manubriotomy was needed in half of the cases when the T-1 corpectomy was the lowest level to be resected (8 cases), and in 4 cases the lowest level to be approached was T-2. The mean surgical time, bleeding volume, postoperative pain intensity, and length of hospital stay were less in the cervicotomy than in the manubriotomy group.

Conclusions. By using the surgeons’ view line and its correlation with the manubrium, the need for manubriotomy can be predicted without compromising decompression and reconstruction. The statistical differences observed in the surgical variables between the manubriotomy and cervicotomy cases justified the use of preoperative evaluation of the need for manubriotomy as an aid to surgical planning and to give the patient and family realistic expectations about the surgery. (DOI: 10.3171/2011.3.SPINE10342)

Key Words • cervicothoracic junction • computed tomography • manubriotomy • anterior surgical approach • surgical technique

The CTJ is defined as the area extending from vertebral segments C-7 to T-4, and it includes the lower brachial plexus, the thoracic outlet, and the parenchymatous, vascular, lymphatic, and nerve structures of the upper mediastinum.21,29,40,48,57 The main features that predispose the CTJ to injuries are the transition area from a mobile, lordotic cervical spine to a rigid, kyphotic thoracic spine;3 weight transfer from the anterior to the posterior column;41 and decrease of the vertebral index from the C-6 to the T-1 vertebrae.5 Pathological processes such as tumors, trauma, degeneration, and infection, which usually occur in the anterior segment of the vertebrae, commonly lead to instability,8 kyphosis, and spinal cord compression; neurological involvement is a common complication, with rates as high as 80%.2,48

Different surgical approaches to the CTJ have been previously described.2,4–6,12,13,14,16–18,20,23–25,27,28,30–32,34–37,40,42,44,46,48,50,52–54,56 The posterior approaches to treat these lesions had limitations such as the difficulty encountered in performing ventral spinal cord decompression, the instability caused by the procedure itself, the complexity of reconstruction, and the greater number of vertebral levels used for the fixation technique.2,11,28,31,53,59 Because most pathological entities affect the anterior column, often an anterior approach is the best option to achieve the surgical goals, which are neural decompression, restoration of anatomical spinal alignment, and immediate stabilization to allow early rehabilitation.4–8,10,12,17,18,22–24,32,33,35–37,40,42,45,48,50,52,53,55,56 The difficulty of the surgical technique resides in the CTJ characteristics: narrowed operative field; bony obstruction...
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by manubrium, clavicle, and ribs; and a greater number of vital anatomical structures nearby, such as great blood vessels, esophagus, trachea, recurrent laryngeal nerve, thoracic duct, and sympathetic ganglia.13,14,20,24,37 The vascular anatomy must be evaluated preoperatively to identify the anomalous course of the most common vessels, which are the BCV and the aortic arch, and to decide whether the anterior approach is feasible.3,14,17,22,26,36,49,50,56,58 Performing manubriotomy increases surgical time, bleeding, postoperative morbidity, and the likelihood that it can be performed without compromising the vertebral canal decompression and the reconstruction, despite the restricted working area.

Methods

Study Design and Cases

This study was based on a prospective consecutive cohort of 19 patients with lesions in the CTJ that were surgically treated via an anterior approach. The patients had an unstable lesion of the VBs between C-7 and T-4 associated with ventral spinal cord compression or disc herniation. All patients underwent MR imaging and CT scanning preoperatively. The MR imaging study was performed to obtain more details about the disease and to identify any vascular anomaly that could contraindicate the anterior approach. Because the anterior approach was feasible, the cervicothoracic sagittal CT reconstruction was done at the midline, including the manubrium, to identify in which cases manubriotomy was needed. According to the radiological preoperative planning, the patients underwent a standard cervical supramanubrial or a transthoracic approach. The procedures were done by the same surgeons (A.F., O.R.). All patients in this study signed informed consent statements.

Preoperative MR Imaging Evaluation of the Great Blood Vessels

Magnetic resonance imaging was done preoperatively to study the disease features and to assess the vascular anatomy to identify the presence of vessels with an anomalous course, which are usually the BCV and the aortic arch, to decide the feasibility of the anterior approach. It is important to evaluate these vessels at the midline, which will be the working area, and which is parasagittal to the side to be accessed. The higher location of the great vessels is not related to the need for manubriotomy, but it is a contraindication to the ventral approach.

Preoperative CT Scanning Evaluation for Manubriotomy

The cervicothoracic CT with sagittal reconstruction images at the midline provided a window to include the manubrium examination, which was performed preoperatively to study the inclination of the superior healthy vertebrae, the distal portion of the lesion, and its relation to the superior border of the manubrium. The superior healthy vertebrae are the first normal ones above the diseased levels in corpectomy cases, or the vertebra above the herniated intervertebral disc in discal herniation cases (Figs. 1 and 2).

The so-called surgeons’ view line was defined as a line parallel to the inferior plateaus of the superior healthy vertebrae and its correlation with the manubrium. If the surgeons’ view line crossed above the manubrium, the manubriotomy was not necessary; otherwise it was performed (Figs. 1 and 3).

It was important to know the inclination for the superior healthy vertebrae, because a parallel visualization of the inferior plateaus was needed to attain a suitable exposure for optimal surgical decompression and fusion with instrumentation. During the CT examination, the patient’s cervical spine was extended and placed in traction, trying to turn the vertebral plateau more horizontally, to have a better chance to perform the surgery without manubriotomy (Fig. 4).

Cases Requiring VB Resection

In 1-level corpectomy cases, the level of the vertebral lesion is not critical to predict the need for manubriotomy, and the indication for this technique only depends on the superior healthy VB inclination. There are 2 reasons for this statement: first, if the healthy vertebrae above the lesion have a marked inclination, the surgeons’ view line of the superior vertebral canal will be difficult and will limit the proximal decompression, despite the VBs’ relation to the manubrium. Second, the relationship between the distal portion of the diseased vertebrae and the manubrium does not matter, because extensive exposure is gained after corpectomy, allowing distal vertebral canal decompression, and stabilization becomes feasible because the placement of distal screws follows an inferior and posterior trajectory (Figs. 1 and 3–5).

In corpectomy cases performed at 2 or more levels, the distal part of the lesion is as important as the superior healthy VB inclination. In these cases, 2 factors need to be assessed: the surgeons’ view line and the lowest level of the diseased vertebrae. The manubriotomy was necessary if the surgeons’ view line was behind the manubrium or the lowest VB to be resected was below the upper border of the manubrium.
Cases Requiring C7–T1 or T1–2 Discal Herniation Removal

The need to perform the manubriotomy only depends on the relationship between the surgeons’ view line and the manubrium. It is important that the view line be parallel to the inferior plateau to allow broader decompression (Fig. 2).

Surgical Procedure and Postoperative Care

The CTJ was approached anteriorly from the side of

Fig. 1. A T-1 corpectomy case with the surgeons’ view line crossing above the manubrium (A). The surgeons’ view was adequate to perform the proximal vertebral canal decompression (B). The surgeons did not have to worry about the distal level of the vertebrae to be resected, because once the corpectomy was done they were able to decompress the distal part of the vertebral canal (C). Furthermore, the inferior screws point in an inferior direction, so their placement will not be disturbed by the manubrium (D).

Fig. 2. Herniated disc case (C7–T1) with the surgeons’ view line crossing above the manubrium (A). The surgeons’ view was adequate to perform C7–T1 discectomy and the vertebral canal decompression (B). The intervertebral device placement (C) and the instrumentation were performed. Clearly the inferior screws point in an inferior direction, so their placement will not be disturbed by the sternum (D).
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The patient was placed supine on the operating table after induction of general endotracheal anesthesia. The neck was moderately extended using a folded sheet, and traction was applied. Both shoulders had traction bands applied to pull the arms down for lateral radiographic imaging during the procedure. A vertical incision was made along the medial aspect of the sternocleidomastoid to the midline, and a standard cervical supramanubrial approach was performed. The neck dissection was completed in a standard fashion. The level of vertebral dissection was confirmed by fluoroscopy.

If a manubriotomy was necessary, the skin incision extended along the midline of the sternum down to 2 cm from the Louis angle (sternal angle). The sternomastoid, sternohyoid, and sternothyroid muscles were sectioned, allowing exposure of the lower cervical region to the upper thoracic spine. A careful finger dissection was used to free the posterior tissue of the manubrium. After that, the bone was excised at midline by using an oscillating saw up to the sternal angle to preserve the sternoclavicular joints. Then, a small self-retaining Finochietto retractor was used to spread the manubrium borders. The great vessels were protected and gently retracted downward if more exposure was necessary.

The lesion was removed with the aid of a headlight and magnification or operating microscope. In cases of corpectomy, the surgeons should be worried about the adequate view of the proximal site of the lesion, because in the distal portion we observed a wider view after VB resection. The epidural bleeding was controlled with hemostats. The distance between the superior and inferior VBs was measured to define the length of the intervertebral device.

The reconstruction was done using an anterior cervical plate system (Zephir; Medtronic, Inc.) and an intervertebral device such as titanium mesh or PEEK in cases of vertebrectomy or discal herniation removal, respectively. The anterior plate had to be narrow to fit into the CTJ working space. The intervertebral device position must be assessed during the surgery with anteroposterior and lateral radiographic imaging views to perform a better reposition (Fig. 5).

A suction drain was always left in the prevertebral space for 48 hours. Another suction drain was left at the substernal plane for 5 days in cases in which manubriotomy was performed. The manubrium was reapproximated with No. 3 steel wires. The patients who underwent manubriotomy were kept in the ICU for 48 hours, and then discharged to a hospital room. The patients were allowed to sit on the bed on the 3rd postoperative day, to sit out of bed with orthosis on the 5th postoperative day, and were progressively free to ambulate. The patients who did not undergo manubriotomy were discharged to a hospital room approximately 6 hours after the procedure; they were allowed to sit up in bed 24 hours after the procedure and to get out of bed on the next day, and they were free to ambulate using a cervical orthosis.

Surgical Evaluation

Recorded surgical variables are surgical duration and intraoperative bleeding. The incision pain intensity was assessed using a numerical rating scale, ranging from 1 (minimal pain) to 10 (maximal pain) 48 hours after surgery. The hospitalization time was recorded as time until discharge home.

Statistical Analysis

All statistical analyses were performed using the SPSS software, version 16.0. Categorical variables were presented as number and proportion. Continuous vari-

Fig. 3. A T-1 corpectomy case in which the surgeons’ view line is not parallel to the inferior plateau of the superior healthy vertebrae; it is clearly shown by the double arrow that this line is crossing behind the manubrium (A). After the manubrium is split (B), the surgeons’ view was adequate to perform the proximal vertebral canal decompression (C). Once the corpectomy was done, the surgeons were able to decompress the distal part of the vertebral canal (D). The inferior screws point in an inferior direction, so their placement will not be disturbed by the sternum (E).
ables were submitted to the Shapiro-Wilk test to verify normal distribution, and are presented as the mean ± SD. To verify differences between the manubriotomy and cervicotomy groups, the surgical time, bleeding, and LOS were compared using the Student t-test.

Results

We present 19 consecutive patients with anterior cervicothoracic lesions who were treated via an anterior approach (Table 1). The mean age was 63 years (range 30–80 years), and 10 patients were men. The majority of the patients (11) had metastatic disease, 5 had disc herniation, 1 had trauma, and 1 had spondylodiscitis. The initial symptoms were severe local pain in all cases, except in the one with trauma (Case 4). The clinical and surgical features of the sample are summarized in Table 1.

Indications for Manubriotomy

The preoperative surgical planning performed as described in the methodology to predict the need for manubriotomy was always correct. In patients who needed a C-7 corpectomy or a C7–T1 discectomy, manubriotomy was never necessary. Manubriotomy was needed in half the cases when the T-1 corpectomy was the lowest level to be resected (8 patients). Nevertheless, in the cases in which the lowest level to be approached was T-2 (5 patients), the manubriotomy was performed in all but 1 patient.

If just half the diameter of the great vessels crossed the surgeons’ view line, the surgery could be done with a slight retraction of this vessel without performing a manubriotomy.

Fig. 4. Case 9. A: The surgeons’ supramanubrial view was parallel to the inferior border of C-7 (arrows), and this line was above the superior border of the manubrium (asterisk). During the CT examination the patient’s cervical spine was extended and traction was applied to turn the vertebral plateau more horizontally. B and C: The manubriotomy was not necessary, and a standard left cervical supramanubrial approach was performed.

Fig. 5. Case 8. A: Although the T-1 and T-2 VBs were above the supramanubrial border, the angle of the superior plateau of T-1 did not allow the surgeons to visualize the vertebral canal from a supramanubrial perspective. B and C: In this case, manubriotomy was necessary. The anteroposterior radiographic views obtained during surgery were unable to show the spine clearly, and the intervertebral device was malpositioned. A posterior fixation of the spine was done because it was not possible to use an anterior plate, and the spinal instability was severe.
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<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Clinical Manifestations†</th>
<th>Level</th>
<th>Pathological Entity</th>
<th>Op Approach</th>
<th>Reconstruction</th>
<th>Op Time (hrs)</th>
<th>Bleeding (ml)</th>
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* Fx = fracture; met = metastasis; NRS = numerical rating scale; pst = posterior.
† Grades are based on the Medical Research Council scale (1976).
Surgical Procedure and Evaluation

In the patients who underwent manubriotomy, more surgical time was necessary, more bleeding and postoperative pain occurred, and the LOS was longer than in the patients who had a standard cervical approach. The mean surgical time was 3.77 ± 0.73 hours in the manubriotomy group and 2.20 ± 0.53 hours in the cervicotomy group (p < 0.0001; mean difference between groups 1.56 ± 0.92 in the cervicotomy group and 2.20 ± 0.53 hours in the manubriotomy group; 95% CI 1.05–2.67). The mean difference in bleeding volume between groups was 177.54 ml (p = 0.004; 95% CI 69.76–279.32; manubriotomy 280 ± 122.24 ml; cervicotomy 105.45 ± 56.63 ml). The mean postoperative pain, measured using a numerical rating scale, was 8.75 ± 0.70 in the manubriotomy group and 3.36 ± 0.92 in the cervicotomy group (p < 0.0001; mean difference between groups 5.38; 95% CI 4.56–6.19). The manubriotomy group stayed in the hospital for 10.12 ± 7.35 days on average, longer than the standard cervical group, in which the LOS was 2.68 ± 1.76 days (p = 0.005; mean difference between groups 7.44 days; 95% CI 2.62–12.25). In the cervicotomy group, there was no statistically significant difference between the patients with discal herniation compared with those with vertebral tumors. All patients demonstrated significant relief from preoperative pain and important neurological recovery. The patients in Cases 4 and 8 underwent a posterior fixation plate and the spinal instability was severe.

Postoperative Complications

There were surgical complications in 2 cases. In both cases manubriotomy was performed. One patient (Case 8) had a local hematoma that was diagnosed 72 hours after surgery, resulting in permanent dysphonia despite the rapid evacuation, and the other complication was a lung infection (Case 3).

Discussion

Several surgical approaches to the CTJ have been described in the literature.2–4,6–11,13,14,16–18,20,22–25,27,28,30–32,34–37,40,42,44,46,48,50,52–54. Posterior approaches are disadvantageous because of a destabilization effect, inadequate visualization of the VB disease, and the need for a long posterior construct to restore stability, with a higher rate of complications than anterior or lateral approaches.2,7,11,23,28,51,53,54,59 These limitations constrain the further development of various posterolateral and anterior approaches.4,6,7,10,16–18,20,22,24,25,27,28,30–32,34–37,40,42,44,46,48,50,52,55,56 The postero lateral approach to the cervicothoracic area was described by several surgeons.1–3,6,16,21,23,27,34,45 The disadvantages of this procedure are prolonged surgery (10–12 hours), excessive blood loss, and inefficiency in treating pathological entities extending into the C-7 vertebra.28 Furthermore, lung-related complications are common following this approach.45 The upper anterolateral transthoracic or extrapleural approach is indicated for total removal and reconstruction of lesions of the CTJ and below to T-4.25 Despite the high mortality rate reported by Hodgson and colleagues,12,20 following an anterior surgical procedure involving the CTJ, many authors believe that the direct anterior approach to the region is safe and effective, as demonstrated in our cases.8,9,18,23,32,33,35,37,40,44,48,55,56

In 1985, Louis improved the sternal splitting approach, combining this procedure with the anterior Smith-Robinson approach,46 to obtain access from C-2 to T-5.24 Nevertheless, sternotomy was related to higher surgical morbidity and mortality rates.2,3,20,24,37,39 The partial sternotomy or manubriotomy was developed to diminish the morbidity of total sternotomy.10,24,36,55 In some selected cases we may even need to perform the manubriotomy to approach the CTJ.9,13,14,17,18,22,42,44,50,52,56 In these cases a standard anterior supramanubrial cervicotomy can be used to reach the proximal thoracic vertebrae.9,13,14,17,18,22,42,44,50,52,56 The features to be assessed to predict manubriotomy were the superior healthy vertebral inclination and the patient’s anatomical characteristics, such as marked junctional kyphosis, congenital high sternum, short neck, or anatomical vascular features.5,11,13,14,23,36–38,49,56,58

Performing manubriotomy increases morbidity, and it is important that the surgical team and the family be made aware, during the preoperative period, of the real need for manubriotomy.7,14,17,20,22,24,26,36,37,49,50,52,56,58 The radiological methods used to identify the need for manubriotomy preoperatively were studied by several authors, but the reproducibility of the technique was not straightforward. Several different measurements were described and analyzed, but these lacked consideration of the vascular anatomy, and the relationship between the inclination of the vertebral plateau and the manubrium was not taken into account.17,22,25,27,28,30–32,34,37,40,42,44,46,48,50,52,55,56 The need to perform the manubriotomy depends primarily on the surgeons’ view line; that is, the relationship between the superior plateaux inclinations of the upper healthy vertebrae and the superior border of the manubrium. The importance of the inclination of the superior healthy vertebrae is that to have a suitable view for optimal proximal surgical decompression and reconstruction, it is necessary to have a parallel visualization of the inferior plateaux (Figs. 1–3). This observation is so important that we perform CT scanning with the patient’s cervical spine in moderate extension and traction to know exactly our best chance to do the surgery without manubriotomy. All these efforts are justified because the standard low cervical supramanubrial approach is familiar to spine surgeons and is less traumatic, as demonstrated in our cases, in which surgical time, intraoperative bleeding, postoperative pain intensity, analgesic medication, and LOS were higher in the manubriotomy group, and the only 2 complications observed in our series, a local hematoma and a lung infection, were in manubriotomy cases.14 Caution should be used if, despite these maneuvers, the surgeons’ view line intersects behind the manubrium; in that case we perform a manubriotomy. In cases of multilevel corpectomy the distal part of the lesion site is also important, with manubriotomy being necessary if the lowest VB to be resected is below the upper border of the manubrium. These radiological methods are useful, straightforward, and readily applicable clinically.

In our experience, the manubriotomy was not necessary in cases of C-7 corpectomy or surgical removal of

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C7–T1 herniated disc. These observations were also confirmed by Post et al. The manubriotomy was needed in half the cases (4 of 8), when the T-1 corpectomy was the lowest level to be resected, and in most cases the lowest level to be approached was T-2 (4 of 5 cases).

The current idea that whenever the vertebral body to be resected is above the manubrium, the visualization of the proximal corner of the vertebral canal for decompression will always be possible, and therefore, the manubriotomy is not necessary, is not correct because the surgeons’ view line depends on the vertebral inclination. Furthermore, the lowest diseased level does not necessarily follow this rule; the superior plateau of the lowest healthy vertebra did not have to be parallel to the surgeons’ view line, because after the corpectomy extensive exposure would be gained, with enough space to decompress the distal portion of the vertebral canal, and the distal screws had an inferior and posterior trajectory, so that the manubrium would never disturb their placement (Figs. 3 and 5).

In corpectomy cases the reconstruction was performed with titanium mesh and an anterior cervical plating system with excellent stabilization, because the posterior elements were normal. The position of the intervertebral device must be assessed during surgery to avoid the malpositioning observed in Fig. 5, where the anteroposterior radiographic views obtained during surgery were unable to show the spine clearly. In discal herniation cases, PEEK was used in combination with the anterior cervical plating system. The anterior cervical plate must be narrow to fit into the CTJ. Uninstrumented laminectomy and ventral multilevel corpectomies (2 or 3 levels) across the CTJ were associated with fusion failure in 38% and 16.7% of cases, respectively. Supplemental dorsal instrumentation was indicated in cases of multilevel corpectomies, posterior instability, or dorsal cervicothoracic laminectomies with extension of the dorsal hardware to T-1 or T-2. In Cases 4 and 8, an anterior decompression followed by a posterior stabilization was performed because of posterior ligamentous and osseous instability.

When performing the anterior approach to the CTJ it is important to know the upper limits of the vascular structures, such as the BCV, the aortic arch, and the brachiocephalic arterial trunk. The vascular anatomy plays a role in contraindicating the anterior procedure, but does not define the need for a manubriotomy. The position of the vessels must be studied at the midsagittal view with inclusion of the manubrium allows the team to assess the surgeons’ view line and its relationship to the manubrium, a method that is simple to apply and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary.

Conclusions

Simply performing the manubriotomy increased the surgical time, intraoperative bleeding, postoperative complications, postoperative pain intensity, and LOS. Preoperative radiological evaluation with CT scanning in the midsagittal view with inclusion of the manubrium allows the team to assess the surgeons’ view line and its relationship to the manubrium, a method that is simple to apply and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. It is crucial to know the requirement and effective in predicting the cases in which manubriotomy is necessary. 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