Mini-open anterior approach to the cervicothoracic junction: a cadaveric study

Yi-xing Huang · Nai-feng Tian · Yong-long Chi ·
Sheng Wang · Jun Pan · Hua-zi Xu

Received: 7 October 2012 / Revised: 4 March 2013 / Accepted: 30 March 2013 / Published online: 8 April 2013
© Springer-Verlag Berlin Heidelberg 2013

Abstract

Purpose To investigate the feasibility of mini-open anterior approach to the cervicothoracic junction (CTJ) in cadaveric specimens.

Methods Four adult fresh-frozen cadaveric specimens were used for this study. On the cadaveric specimen, an osteotomy window was made in manubrium sterni to remove the bony obstacle. To bypass the vital vascular and neural structures over the operative field, we used the surgical corridor which was located medially by the brachiocephalic artery and laterally by the right brachiocephalic vein, or in combination with another surgical corridor between the ascending aorta and the superior vena cava. And we used a special self-retaining retractor system and an endoscope to facilitate the procedures.

Results Surgical procedures performed on the four fresh-frozen cadaveric specimens to expose the CTJ through mini-open anterior approach were successful. The anterior surface of C6–T5 could be exposed, allowing complete decompression and application of locking plate and screws. The most caudal accessible vertebral body was T5 vertebral body in our study.

Conclusion It is feasible to expose the CTJ through this mini-open anterior approach.

Keywords Cervicothoracic junction · Anterior approach · Mini-open approach · Cadaveric study

Introduction

The cervicothoracic junction (CTJ) is usually defined by many authors as an area extending from C7 to T4 [12, 17, 22]. Anterior approaches to the CTJ remain challenging because of the close proximity of vital vascular and neural structures over the operative field and the osseous obstacles caused by the manubrium sterni, clavicles and ribs [15, 17, 22, 23].

Anterior surgical approaches such as the trans-sternal [3], the transclavicular trans-manubrial [1, 4, 18] and trans-manubrial [19, 22, 25] approaches have been recommended. From the spinal and cardiothoracic literature, however, it is clear that splitting the sternum or resecting part of clavicle might lead to some complications, such as chronic pain, pneumothorax, infection, sternal dehiscence, nonunion of the clavicle, pseudarthrosis, and instability of the sternoclavicular joint [1, 5, 7, 13, 20, 22].

In order to minimize surgical complications, we attempted using a mini-open anterior approach to the cervicothoracic junction. The primary goals of this study were to assess the feasibility of this technique.

Materials and methods

Four intact adult fresh-frozen cadaveric specimens (3 males and 1 female) with normal cervicothoracic junction were obtained for surgical procedures according to protocols from the anatomy department. And this study was approved by the Institutional Ethics Review Boards. A special self-retaining retractor system and an endoscope were used to facilitate the procedures.

Cadaveric specimen was placed supine with the neck hyperextended and the head rotated to the left side. For a

Y. Huang · N. Tian · Y. Chi · S. Wang · J. Pan · H. Xu (✉)
Department of Orthopedic Surgery, Second Affiliated Hospital
of Wenzhou Medical College, 109 Xueyuan Road,
Wenzhou, China
e-mail: sunnyknight@126.com

better exposure, a rolled towel was placed between the scapulas. A midline longitudinal incision was made from the suprasternal notch to the sternal angle. The cephalic part of the incision could be extended along the anterior border of the sternocleidomastoid muscle on the right side if required.

The anterior cortical and cancellous bones of the manubrium from the suprasternal notch to the sternal angle were removed by using a bone rongeur. The bilateral sternoclavicular joints and 4- to 8-mm-thick cortical bones in outer margin were preserved (Fig. 1). Then, the posterior surface of the manubrium was freed by blunt dissection with a finger and the retrosternal structures were pushed away. The posterior cortical bone was removed bit by bit and the posterior periosteum of the manubrium was preserved in order to reduce the risk of injuring the retrosternal structures such as pleura and thymus (Fig. 2). These

Fig. 1 A drawing of window osteotomy in manubrium—the blank area represents the area of bone resection

removed bones could be reimplanted to reconstruct the manubrium or can be used as bone graft. After the osteotomy window in the manubrium was made, the posterior periosteum of the manubrium was exposed. A longitudinal incision was carefully made on the periosteum, and the anterior aspect of superior mediastinum was exposed. By blunt dissection in the superior mediastinum, great vessels such as the brachiocephalic artery (BCA), the left and right brachiocephalic veins could be identified (Fig. 3). We

Fig. 2 A window osteotomy was made in the manubrium. The posterior periosteum of manubrium and the superior mediastinum were exposed. 1 left and right sternoclavicular joints, 2 posterior periosteum of the manubrium, 3 superior mediastinum, 4 residual bone in the lower part of the manubrium

Fig. 3 An image showing exposure of great vessels in the superior mediastinum. 1 brachiocephalic artery, 2 left brachiocephalic vein, 3 right sternoclavicular joint, 4 left sternoclavicular joint, 5 residual bone in the lower part of the manubrium. Asterisk the surgical corridor which was located medially by the brachiocephalic artery, laterally by the right brachiocephalic vein, and inferiorly by the confluence of the left and right brachiocephalic veins

Fig. 4 Schematic drawings of the surgical corridor which was located medially by the brachiocephalic artery, laterally by the right brachiocephalic vein, and the surgical corridor bordered by the superior vena cava on the right, the ascending aorta on the left (AAO ascending aorta, AA aortic arch, BCA brachiocephalic artery, L-BCV left brachiocephalic vein, L-CCA left common carotid artery, LSA left subclavian artery, R-BCV right brachiocephalic vein, SVC superior vena cava, T4 the fourth thoracic vertebral body)

would use the surgical corridor which was located medially by the BCA, laterally by the right brachiocephalic vein (BCV), and inferiorly by the confluence of the left and right brachiocephalic veins. In order to expose more caudal vertebral bodies, we would use the aforementioned surgical corridor in combination with another surgical corridor bordered by the superior vena cava on the right, the ascending aorta on the left, and the left BCV and BCA superiorly (Fig. 4). Connect the special self-retaining retractor system with a flexible locking arm (Medtronic Sofamor Danek USA, Inc.) which was fixed tightly on the operative table. This special self-retaining retractor system was designed by ourselves. And we made a variety of retractor blades with different length and width. First, a tunnel to the spine was made by blunt dissection. Then, two pieces of long retractor blades were put into the tunnel and immediately connected with the special self-retaining retractor system. The handles were rotated to move the retractor blades and the great vessels were gently retracted. Another two pieces of long retractor blades were put into the tunnel and immediately connected with the self-retaining retractor system. The handles were rotated to move the retractor blades. By using this special self-retaining retractor system, the adjacent vessels and nerves together with the esophagus and trachea were retracted. This could greatly reduce the risk of injuring these important anatomical structures because they were outside the working channel enclosed by the four pieces of long retractor blades. Then, the anterior aspect of the spine was clearly exposed. And the procedures were performed through the working channel. The size of the working channel could be adjusted by rotating the handles to move the retractors blades back and forth. And it was possible to

Fig. 5 Surgical procedures were performed on a fresh cadaveric specimen through a working channel enclosed by four pieces of long retractor blades. And the procedures could be performed with an endoscope

perform the procedures with an endoscope. Also, the endoscope could be connected with the self-retaining retractor system. The handle was rotated to move the endoscope if required. And the height of the endoscope could be adjusted with an adjustable screw nut. By using this method, the anterior surface of the lower cervical and upper thoracic spine could be exposed, allowing complete decompression and application of locking plate and screws (Fig. 5). Finally, sufficient absorbable gelatin sponges were laid between the great vessels in superior mediastinum and the osteotomy window of the manubrium. Posterior periosteum of the manubrium was sutured and the bones removed during window osteotomy were reimplanted onto the posterior periosteum to reconstruct the manubrium. Then, the incision was closed with stitches.

Results

Surgical procedures performed on four fresh-frozen cadaveric specimens to expose the CTJ through window osteotomy in manubrium were successful. The anterior surface of C6–T5 could be exposed, allowing complete decompression and application of locking plate and screws. The most caudal accessible vertebral body was T5

Fig. 6 **a** An intra-operative anteroposterior image showed that T4/5 intervertebral disc was removed and an anterior fixation plate was screwed between T4 and T5. **b** An intra-operative anteroposterior

image showed that subtotal corpectomy of T4 were performed and a locking plate was screwed between T3 and T5

Fig. 7 An intra-operative view of application of locking plate and screws with an endoscope. The endoscope could provide good illumination and magnification of deep structures

vertebral body in our study (Fig. 6a, b). No obvious injury of important vessels and nerves was observed. Additionally, the procedures could be performed with an endoscope if required, especially in the decompressive stage of the procedure. The endoscope could provide good illumination and magnification of deep structures (Fig. 7).

Discussion

Lesions at the CTJ are not rare, but surgical exposure of this region remains challenging. This is especially true for

lesions in the vertebral body, in which an anterior approach is commonly needed. Because of the deep location of vertebral bodies due to the kyphosis of the upper thoracic spine and the presence of neurovascular and osseous obstacles over the operative field in this region, surgical access is often limited [15, 17, 22, 25].

As for neurovascular obstacles, such as the brachiocephalic veins, thoracic duct, and recurrent laryngeal nerves, they can be easily injured which might lead to significant complications [10, 12, 19, 25]. The best way is to bypass them and to reach the spine through neurovascular space.

The osseous obstacles do not always limit the surgical access. When access to T2 and upper levels is required, the traditional anterior low cervical approach is usually enough. A number of previous authors have demonstrated this [9, 12]. But the manubrium sterni and clavicles often hinder access to T3, T4 and below. To gain access, surgical techniques such as the trans-sternal, the transclavicular trans-manubrial and trans-manubrial approaches have been recommended [1, 3, 4, 18, 19, 22, 25]. Each approach has its advocates, but all of them have limitations.

Fielding and Stillwell [8] first reported the anterior low cervical approach to the CTJ in 1976. Subsequently, many authors used this technique to gain access to the CTJ. By using this approach, levels C7–T2 often can be exposed adequately, but an exposure caudal to T2 is usually limited by the manubrium sterni and clavicles.

In 1957, Cauchoix and Binet [3] first described a full median sternum-splitting approach for a chondrosarcoma located at T1–T3. Later, Hodgson et al. [11] applied this method on 10 patients with Pott disease, but observed an operative mortality of 40 %. As a result, they advocated abandoning this method. Other data from the cardiothoracic surgical literature indicated infection rates, ranging

Fig. 8 An MR image shows the location of the suprasternal notch and the sternal angle with respect to the vertebral levels. The suprasternal notch occurs opposite T2/3 and the sternal angle occurs opposite T4/5. Line BE means distal osteosynthesis screws of T5 might be slightly oblique in an inferior and posterior direction

from 0.2 to 10 %, with associated morbidity and mortality rates as high as 25 % [2, 16, 21].

In 1984, Sundaresan et al. [24] presented a transclavicular trans-manubrial approach by removal of a rectangular block of the sternum and resection one-third medial portion of the clavicle. The resection of the clavicle improved exposure and provided a strut graft. They used this approach on seven patients with tumorous lesions at the CTJ, and the most caudal lesion level was T2 vertebral body in their study. This method might cause increased pain, nonunion of the clavicle and shoulder dysfunction.

Thereafter, a modified trans-manubrial approach (unilateral manubriotomy) was used by Darling et al. [6] in 4 cases, by Xiao et al. [25] in 28 cases. This technique could access T4, occasionally T5. However, it provided relatively narrow access to the spine—that is, a width of no more than 4 cm [22]. For more extensive exposure of this area, Luk et al. [22] used another kind of modified trans-manubrial approach (bilateral manubriotomy). This technique could provide an interval of approximately 8 cm between the osteotomized segments of the manubrium. But it needed transverse osteotomy of the sternum and ligations of the bilateral internal thoracic arteries.

To gain access to T4 and below, some authors advocate a lateral parascapular extrapleural approach or even consider a standard thoracotomy. The limitation of these two approaches is the restricted access to the low cervical region and the upper 2 thoracic vertebrae due to the scapula and the remaining ribs [12, 14].

To minimize surgical complications, we attempted to use a mini-open anterior approach. In this study, we

successfully applied this technique on four fresh-frozen cadaveric specimens. We made an osteotomy window in manubrium sterni to remove osseous obstacles. In order to bypass the neurovascular obstacles, we used two different surgical corridors alone or together. The bone resection in manubrium was limited by the sternoclavicular joints laterally, and by the junction between the manubrium and the sternal body caudally. It did not destroy the sternoclavicular joints and could provide an interval of approximately 3–6 cm in the width, allowing access to both sides of the vertebral bodies for complete decompression and application of locking plate and screws. The most caudal accessible vertebral body was T5. Commonly, distal osteosynthesis screws of T5 might be slightly oblique in an inferior and posterior direction. To gain access to T3 and T4, however, resection of upper part of the manubrium might be enough (Fig. 8). And there exists variations among individuals [9, 12]. Osteotomy of the clavicle or ligations of the bilateral internal thoracic arteries were unnecessary in our study. And the procedures were performed through a working channel which was enclosed by four pieces of long self-retaining retractor blades. This could significantly reduce the risk of injuring the adjacent vessels and nerves because they were outside the working channel during the procedures. Especially, the endoscope could provide good illumination and magnification of deep structures. This also could greatly decrease the risk of injuring these important anatomical structures.

However, there might be some limitations in the current study. We used the method of cadaveric study and the sample size was small. The reactions of retracting great

vessels and nerves could not be observed in this study. Therefore, this technique needs further investigation for the safety in clinical practice.

Acknowledgments The research was supported by the National Natural Science Youth Foundation of China (Grant No. 81101395) and the Health Bureau of Zhejiang Province (Grant No. 2011KYA110).

Conflict of interest There is no actual or potential conflict of interest in relation to this article.

References

- Birch R, Bonney G, Marshall RW (1990) A surgical approach to the cervicothoracic spine. *J Bone Jt Surg Br* 72:904–907
- Cabbabe EB, Cabbabe SW (2009) Surgical management of the symptomatic unstable sternum with pectoralis major muscle flaps. *Plast Reconstr Surg* 123:1495–1498
- Cauchoux J, Binet JP (1957) Anterior surgical approaches to the spine. *Ann R Coll Surg Engl* 21:237–243
- Charles R, Govender S (1989) Anterior approach to the upper thoracic vertebrae. *J Bone Jt Surg Br* 71:81–84
- Comey CH, McLaughlin MR, Moossy J (1997) Anterior thoracic corpectomy without sternotomy: a strategy for malignant disease of the upper thoracic spine. *Acta Neurochir* 139:712–718
- Darling GE, McBroom R, Perrin R (1995) Modified anterior approach to the cervicothoracic junction. *Spine* 20:1519–1521
- Eastridge CE, Mahfood SS, Walker WA, Cole FH Jr (1991) Delayed chest wall pain due to sternal wire sutures. *Ann Thorac Surg* 51:56–59
- Fielding JW, Stillwell WT (1976) Anterior cervical approach to the upper thoracic spine. *Spine* 1:158–161
- Fraser JF, Diwan AD, Peterson M, O'Brien MF, Mintz DN, Khan SN, Sandhu HS (2002) Preoperative magnetic resonance imaging screening for a surgical decision regarding the approach for anterior spine fusion at the cervicothoracic junction. *Spine* 27:675–681
- Gieger M, Roth PA, Wu JK (1995) The anterior cervical approach to the cervicothoracic junction. *Neurosurgery* 37:704–709
- Hodgson AR, Stock FE, Fang HS, Ong GB (1960) Anterior spinal fusion. The operative approach and pathological findings in 412 patients with Pott's disease of the spine. *Br J Surg* 48:172–178
- Huang YX, Ni WF, Wang S, Xu H, Wang XY, Xu HZ, Chi YL, He JW (2010) Anterior approaches to the cervicothoracic junction: a study on the surgical accessibility of three different corridors based on the CT images. *Eur Spine J* 19:1936–1941
- Kalso E, Mennander S, Tasmuth T, Nilsson E (2001) Chronic post-sternotomy pain. *Acta Anaesthesiol Scand* 45:935–939
- Kaya RA, Türkmenoğlu ON, Koç ON, Genç HA, Cavaşoğlu H, Ziyal IM, Aydın Y (2006) A perspective for the selection of surgical approaches in patients with upper thoracic and cervicothoracic junction instabilities. *Surg Neurol* 65:454–463
- Kurz LT, Pursel SE, Herkowitz HN (1991) Modified anterior approach to the cervicothoracic junction. *Spine* 16:S542–S547
- Landes G, Harris PG, Sampalis JS, Brutus JP, Cordoba C, Ciaburro H, Bernier C, Nikolis A (2007) Outcomes in the management of sternal dehiscence by plastic surgery: a ten-year review in one university center. *Ann Plast Surg* 59:659–666
- Lehman RM, Grunberg B, Hall T (1997) Anterior approach to the cervicothoracic junction: an anatomic dissection. *J Spinal Disord* 10:33–39
- Lesoin F, Thomas CE 3rd, Autricque A, Villette L, Jomin M (1986) A transsternal biclavicular approach to the upper anterior thoracic spine. *Surg Neurol* 26:253–256
- Liu YL, Hao YJ, Li T, Song YM, Wang LM (2009) Trans-upper-sternal approach to the cervicothoracic junction. *Clin Orthop Relat Res* 467:2018–2024
- Losanoff JE, Jones JW, Richman BW (2002) Primary closure of median sternotomy: techniques and principles. *Cardiovasc Surg* 10:102–110
- Losanoff JE, Richman BW, Jones JW (2002) Disruption and infection of median sternotomy: a comprehensive review. *Eur J Cardiothorac Surg* 21:831–839
- Luk KD, Cheung KM, Leong JC (2002) Anterior approach to the cervicothoracic junction by unilateral or bilateral manubriectomy. A report of five cases. *J Bone Joint Surg Am* 84-A:1013–1017
- Miscusi M, Bellitti A, Polli FM (2005) Surgical approaches to the cervico-thoracic junction. *J Neurosurg Sci* 49:49–57
- Sundaresan N, Shah J, Foley KM, Rosen G (1984) An anterior surgical approach to the upper thoracic vertebrae. *J Neurosurg* 61:686–690
- Xiao ZM, Zhan XL, de Gong F, De Li S (2007) Surgical management for upper thoracic spine tumors by a transmanubrium approach and a new space. *Eur Spine J* 16:439–444