ANATOMICAL CONSIDERATION IN ANTERIOR APPROACH TO THE SUBAXIAL CERVICAL SPINE

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ABSTRACT

Objective : Anterior anatomical relations and measurements of the subaxial cervical vertebrae are essential to safely perform successful anterior cervical surgery and decompression. We studied the anatomy and important measurements of the cadaveric cervical spines to elucidate the relationships between the neurovascular structures and the surrounding bones.

Materials and methods : Our measurements were in adult Egyptian male cadaveric spines. They included the distance between the medial borders of the longus colli muscles (LCM) at the level of each interspace disc; the depth (thickness) of (LCM), the distance between the medial border of (LCM) and vertebral artery (VA); the width and height of each non- distracted disc space at the midline; width and height of the costal process; length of the (VA) between the costal processes; distance from the medial border of the foramen transversarium to the contra-lateral one; the height and width of the uncinate process (UP); the distance between the tip of the UP and the intervertebral foramen above and from the tip of the UP to the VA; the height of the distracted disc space at the midpoint; the distance from the postero-medial end of the UP to the VA and from the postero-medial end of the UP to the nerve root.

Results : The highest of the non-distracted disc space was at C5-C6 while the highest of the distracted disc space was at C3-C4. The width of the costal process was the shortest at C3 and longest at C7. The height

of the costal process was the shortest at C7 and the longest at C5 and C6. The length of the exposed VA between the costal processes increased in a caudal to cranial direction. The thickest part of LCM was at C4-C5. The shortest distance between the medial border of (LCM) and (VA) was at C5-C6. The shortest distance between tip of UP and VA was at C6-C7 while the shortest distance between tip of UP and intervertebral foramen above was at C2-C3. The shortest distance between the postero-medial end of the UP and VA was at C2-C3 while the longest one was at C5-C6. The shortest distance between the postero-medial end of the UP and nerve root was at C2-C3 while the longest one was at C4-C5. All these measurements increased from cranial to caudal direction (the distance between the medial borders of the longus colli muscles, the width of the non- distracted disc spaces, the distance from the medial border of the foramen transversarium to the contralateral one, the height and width of the UP).

Conclusion : The previous measurements provide the surgeon with essential data before doing any anterior cervical surgery to avoid injury of the neurovascular structures.

Keywords : Anterior, Cervical spine, Surgical anatomy, Vertebral artery

INTRODUCTION

The anterior approach to the disc diseases of the cervical spine developed in the 1950s and provided the most direct route to the anterior cervical pathology[1,5,22,26]. The anterior surgical approach to the cervical spine, now, is a commonly used procedure. Henderson[12] argued that posterior fusion, which had no effect on the diseased anatomy, is an ineffective procedure for tuberculosis of the spine. The need for a more effective and radical therapy for Pott's disease prompted the development of different approaches to the anterior spine[13,16,29,30]. Bailey and Badgely [1] noted that in 1952, Abbott first suggested the use of an anterior fusion for a case of a lytic lesion of C4 and C5. Because of the ease of the approach, the technique becomes popular for treating other cervical spine lesions. The treatment of degenerative disc diseases was advanced by Cloward and Robinson and Smith[5,22], who used the technique of interbody fusion.

Intraoperative complications of the anterior cervical spine surgery after dissection of the anterior soft tissue include injury to the nerve root, vertebral artery (VA), and spinal cord. Data collected by Graham[10] suggested that nerve root injuries are more common than spinal cord injuries. Injuries to the VA during anterior cervical spine surgery are infrequent, but they can be catastrophic[8,15,25,27]. Smith et a., [27] reviewed ten cases of such injuries and found the most common cause is the lateral bone resection.

To elucidate the anatomy of the nerve root and VA in the anterior approach, we studied this anatomy in cadaveric cervical spines. We measured important landmarks on the anterior surface of the vertebrae, the bony housing protecting the neurovascular structures in the lateral disc space, and the changes that occur after the discectomy.

MATERIALS AND METHODS

Seven formalin-fixed adult Egyptian male cadavers were used in this work. We did the study on the male cadavers because the female cadavers were not enough. All measurements were made using 1) a protractor to define the distance between points, 2) a Diamond Master Vernier Calipers to measure the distances and 3) an orthopedic goniometer. We made these measurements at the C2-C3, C3-C4, C4-C5, C5-C6 and C6-C7 levels. The soft tissue superficial to the longus colli muscles was removed, and the distances between the medial borders of the longus colli muscles (LCM) were measured at the level of each interspace (Fig. 1). The depth (thickness) of the LCM, the distances from the medial border of LCM to the VA were measured. The width and height of each non-distracted disc space at the midline were measured.

The longus colli muscles were removed. The vertebral artery (VA) and costal processes (anterior bony segment of the foramina transversarium) were exposed. The width and height of the costal processes (CP) were measured. The length of the VA between the costal processes was measured at all levels. The distance from the medial border of the foramen transverserium on one side to the contralateral foramen was also meas-

ured. Later, the disc spaces were excised back to the posterior longitudinal ligament. The height of the distracted disc space at the midpoint was measured (fig. 2).

The VB distraction screws were placed into the VBs. The intervertebral disc was completely removed from each interspace using the technique that described by Caspar et al., [3] The posterior longitudinal ligament was excised and the uncinate processes (UP) were exposed (Fig. 3). The UP was defined as a bony prominence above an imaginary horizontal line extending laterally from the cranial edge of each VB. The height of the UP was measured. The width was measured from the medial to the lateral surfaces of the UP at its midportion site. The distance was measured from the tip of the UP to the intervertebral foramen above and from the tip of the UP to the VA.

The distance from the postero-medial end of the UP to the VA and from the postero-medial end of the UP to the nerve root at all interspaces levels was measured (Fig. 4 &5). The midline A-P diameter, midline width of the vertebral body at its inferior surface after discectomy were measured. Statistical analysis for all measurements was performed using SPSS program.

RESULTS

Some measurements at the interspace levels were listed in the table 1. The distance between the medial borders of the longus colli muscles (LCM) increased in a cranial to caudal direction. The shortest distance between the medial border of LCM and VA was at C5-C6. The width of the non- distracted disc spaces increased in a cranial to caudal direction. The highest of the non-distracted disc space was at C5-C6 while the shortest one was at C4-C5. The shortest distance between tip of UP and VA was at C6-C7 while the shortest distance between tip of UP and intervertebral foramen above was at C2-C3. The length of exposed VA between the costal processes increased in a caudal to cranial direction. The highest distracted disc space was at C3-C4. The shortest distance between the postero-medial end of the UP and VA was at C2-C3 while the longest one was at C5-C6. The shortest distance between the postero-medial end of the UP and nerve root was at C2-C3 while the longest one was at C4-C5.

Tab. 1: Some measurements at the interspace levels The measurements were in mm. All values were presented as the mean and range (minimum- maximum)

	C2-C3	C3-C4	C4-C5	C5-C6	C6-C7
1- The distance between the medial borders of the longus colli muscles	5.6 (4.2-9.3)	6.8 (6.3-11.3)	11.4 (9.2-13.4)	13.5 (11.2-17.6)	23.5 (21.3-26.4)
2- The distances between the medial border of LCM and VA	11.7 (10.3-15.2)	10.1 (9.8-14.6)	9.5 (7.2-12.4)	8.5 (6.5-11.4)	9.9 (10.4-12.5)
3- Depth (thickness) of LCM	4.9 (2.2-5.5)	5.7 (3.6- 9.4)	8.4 (7.4- 12.5)	6.9 (5.7-10.2)	7.3 (6.2- 11.8)
4- The width of the disc space	22.8 (19.2-27.8)	23.3 (20.2-25.2)	26.2 (22.9-27.9)	27.9 (25.0- 9.9)	28.7 (25.9-31.1)
5- The height of the non-distracted disc spaces	4.1 (2.2- 6.3)	4.3 (2.1-6.7)	3.4 (0.8- 5.5)	4.6 (2.4- 7.1)	4.4 (2.2- 6.9)
6- The distances between tip of the UP and VA	2.6 (0.8-3.1)	2.6 (1.2-2.3)	2.9 (1.1-4.1)	2.7 (1.0- 4.0)	2.5 (1.1- 2.9)
7- The distances between tip of the UP and intervertebral foramen above	1.0 (0.5- 2.1)	1.2 (0.6- 2.3)	1.3 (0.5- 2.2)	1.5 (0.5- 2.7)	1.4 (0.5- 2.5)
8- The length of exposed VA between the costal processes	14.0 (12.9-16.1)	13.2 (12.0-15.2)	11.1 (9.9- 13.1)	10.1 (9.1- 12.3)	
9- The heights of the distracted disc spaces	8.6 (6.2- 9.1)	8.8 (6.1- 10.1)	8.7 (6.0- 10.0)	8.6 (6.0- 9.0)	8.6 (6.1- 9.1)
10- The distances between the postero-medial end of the UP and VA	6.1 (4.2- 9.3)	7.2 (6.2- 10.2)	8.2 (7.1-12.1)	9.3 (8.2-14.2)	8.2 (7.1-13.2)
11- The distances between the postero-medial end of the UP and nerve root	2.5 (2.0- 4.2)	3.1 (2.5- 4.8)	4.2 (3.7- 5.9)	3.1 (2.4- 4.7)	3.0 (2.5- 4.7)

Tab. 2: The measurements of some bony structures at each vertebral levels.The measurements were in mm. All values were presented as the mean and range (minimum- maximum).

	C3	C4	C5	C6	C7
1- Height of UP (increased from cranial to caudal direction)	4.8 (3.4- 7.8)	5.6 (4.1- 8.2)	5.8 (4.1- 8.5)	6.3 (4.2- 8.5)	6.5 (4.4- 8.6)
2- Width of UP (increased from cranial to caudal direction)	5.2 (3.3- 6.9)	5.3 (3.4- 6.9)	5.5 (3.4- 6.9)	5.6 (3.5-7.0)	5.8 (3.5-7.1)
3- Height of the costal process	8.1 (6.1- 12.2)	8.4 (7.3- 12.3)	10.9 (8.5- 13.6)	10.9 (8.6- 13.5)	The smallest 7.3 (5.5- 11.3)
4- Width of the costal process (increased from cranial to caudal direction)	11.3 (9.1-13.2)	12.0 (10.1- 15.1)	13.8 (12.2- 17.8)	16.9 (15.6- 21.0)	22.8 (21.8-26.8)
5- Midline A-P diameter of VB	13.9 (10.2-13.5)	14.7 (13.6- 21.4)	The widest 18.4 (14.4- 22.5)	15.9 (12.7-19.2)	16.3 (13.2-19.8)
6- Midline width of the VB at its inferior surface (increased from cranial to caudal direction)	16.3 (13.3-21.1)	17.3 (13.6-21.5)	18.5 (14.3-22.5)	19.5 (16.9-22.8)	20.8 (17.4- 23-4)
7- Distance from the medial border of the foramen transverserum to the contra-lateral foramen (increased from cranial to caudal direction)	28.1 (25.6- 32.2)	28.9 (26.2- 32.8)	30.1 (26.8- 33.3)	31.2 (26.9- 33.5)	32.6 (28.1-33.8)

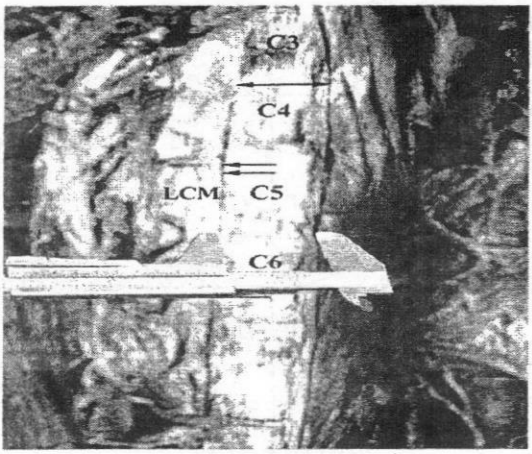

Fig. 1 : The superficial soft tissues are removed. The longus colli muscle (LCM) and cervical vertebrae (C3-C7) are seen. The distance (between the heads of the arrow) between the medial borders (double arrows) of the longus colli muscles is measured.

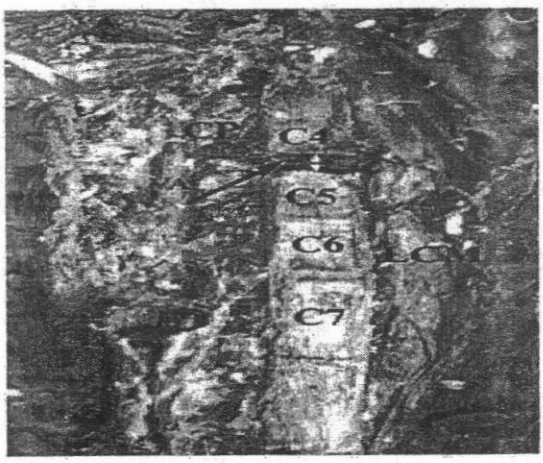

Fig. 2 : The right longus colli muscle is cut. The intervertebral disc between C4-C5 is removed. The height (between the heads of the arrow) of the disc space (arrow) is measured. The vertebral artery (VA) and costal process (CP) are seen.

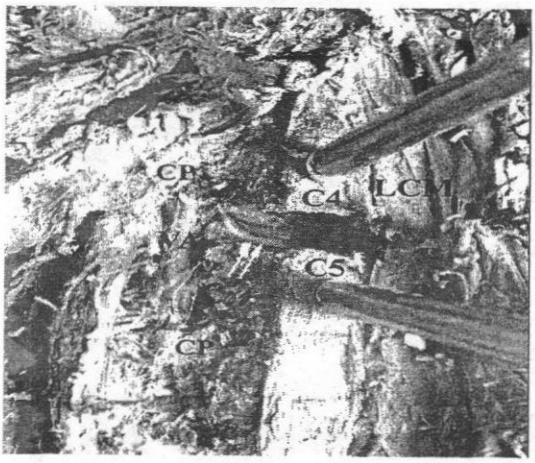

Fig. 3 : The right longus colli muscle is cut. VB distraction screws are placed into the VBs (C4-C5) and the intervertebral disc is removed. The uncinate process (double arrows), vertebral artery (VA) and costal processes (CP) are seen.

Fig. 4 : The disc between C4-C5 is distracted. The vertebral artery (VA) and costal process (CP) are seen. The uncinate process (*) is removed. The nerve root (N) passes behind the vertebral artery (VA).

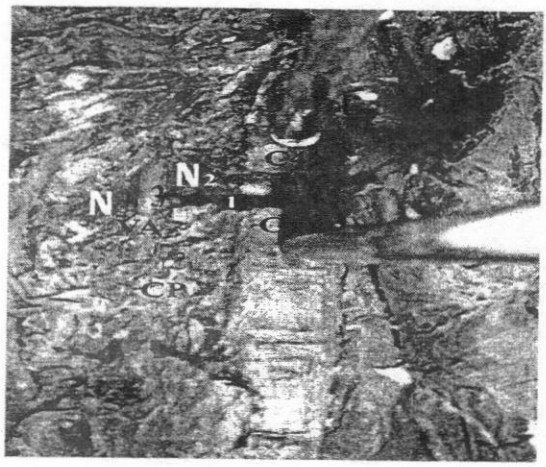

Fig. 5 : This photo shows the removed uncinate process (Nr. 1), beginning of the nerve root (N, Nr. 2) and vertebral artery (VA, Nr. 3).

DISCUSSION

Knowledge of the quantitative anatomic relationships of the cervical vertebral bodies is essential to ensure adequate removal of bony structures without compromising the stability or damaging of the spinal cord, nerve roots, or vertebral arteries[24].

In cases of surgical vertebral artery injury, management by lateral exposure may be needed [7,9,21,28]. To avoid these injuries, the longus colli muscles should be dissected and both the costal process (CP) and the uncinate process (UP) should be removed. This indicates that the surgeon must know well the anterior anatomy of the cervical spine specially the hidden lateral structures.

Injuries to the VA and nerve root are uncommon but serious complications of anterior cervical spine surgery were reported by Hong et al.,[14] The true incidence of VA injury during anterior cervical spine surgery is unknown because of underreporting of such occurrences[8,9]. Hong et al.,[14] reported that the incidence of vertebral artery injury was 0.3% to 0.5%. The best means of preventing complications is possessing knowledge of the surrounding anatomy that

is not in direct view. To gain this understanding, we used cervical spines from seven Egyptian male adult cadavers to measure the important landmarks encountered in this approach, placing an emphasis on the bony surroundings of the neurovascular elements in the lateral disc space.

The longus colli muscles extend longitudinally along the ventral surface of the VBs between the atlas (C1) and the third thoracic vertebra (T3). The medial borders of these muscles have been suggested as a landmark to determine the safe lateral margins for a cervical corpectomy [20,21,27].

Our data demonstrated that the distance between the medial borders of both muscles increased in a caudal direction. The average distances were 4.6 mm at C2-C3 and 23.5 mm at C6-C7. These findings are in agreement with the results of Pait et al and Saringer et al., [19,23]. In contrast, our results slightly differ from that of Oh et al.,[18] who found that distances increased from 9.28 mm at C3 to 14.19 mm at C6 and slightly decreased at C7. However, considerable variability occurred at each level. Therefore, using the medial border of the longus colli as a landmark should be done with caution because doing so may leave bony parts behind that should be removed.

The costal process (CP) is the anterior boundary of the foramen transversarium, lying ventral to the VA. In our study, the CP height was found to increase from rostral to caudal direction then become the narrowest at C7. The width of the costal process increased from cranial to caudal direction. We also found that, the length of exposed VA between costal processes increased in a caudal to cranial direction, thus risk of injury of the exposing VA during procedures increased at the cephalic levels. These results are compatible with the results of Kawashima et al., and Pait et al.,[17,19]

The UP is located on the superior surface of the cervical VBs, except the first and second vertebrae. With aging, the UP may lose its sharp, tapered configuration and become flattened[2]. The height and width of the UP increased from cranial to caudal direction. These findings agrees with

the results of Saringer et al.,[23] and is different from that of Civelek et al., and Pait et al., [4,19] who found that, the height is the shortest at C4-C5 and the longest at C5-C6 and the width was the narrowest at C4-C5 and the widest at C6-C7.

From the results of the work, the anteroposterior (depths) of the VB at the inferior endplate increased from 13.9 mm at C3 to 16.3 mm at C7 and was longest at C5 (18.4 mm). The midline width of the VB at its inferior surface also increased from cranial to caudal direction. Our results are in agreement with the findings of Oh et al., and Saringer et al., [18,23]. These measurements are useful for determining the size of the interbody graft and for placing vertebral body screws in anterior plate fixation.

In the present study, we used formalin-fixed specimens which render the soft tissue structures stiffer and less elastic. Therefore, the measurements obtained in this study with distraction may be conservative and the window of injury may be greater than reflected in our results and this agrees with the opinion of Pait et al., [19]. They [19] noted that sharp dissection should be performed in a lateral to medial direction to avoid injury of the VA. The distance from the tip of the UP to the VA averaged 1.5 mm (minimum 0.8 mm) at C2-C3 and 1.9 mm at C4-C5. These measurements are compatible with the results of Pait et al.,[19], but Saringer et al.,[23] found that the minimum was 1.5 mm at C4 and the maximum was 2.3 mm at C3 in live endoscopic study. Therefore, when the UP is identified, it is important to appreciate that the VA is intimately associated with the lateral border of the UP. Caution should be exercised when the UP is removed in an attempt to remove osteophytes.

Oh et al.,[18] said that the extent of transverse decompression in cervical spondylosis with myeloradiculopathy depends on the spinal dimensions. A decompression of 15 to 18 mm in a transverse direction has been advocated for all cervical spine levels. Their study showed that, the distances between the medial margins of both Luschka joints varies greatly, increasing from 15.18 mm at C3 to 20.28 mm at C7. Therefore, the use of fixed values for decompression

throughout the spine may not be appropriate and may lead to inadequate decompression at lower cervical levels. They recommend that in cases of myelopathy, decompression should extend at least from one Luschka joint to another and that in cases of radiculopathy with foraminal stenosis, decompression should extend further laterally (i.e., until the nerve root is decompressed but not exceeding 5-6 mm). In the present study we tried to use an important landmark which is postero-medial end of UP as it could be palpated or seen in the depth of distracted disc. The average distance between the postero-medial end of UP and VA at the interspace level was minimum at C2-C3 (8.1 mm) and maximum at C5-C6 (16.3 mm). The average distance between the postero-medial end of UP and nerve root at the interspace was minimum at C2-C3 (2.5 mm) and maximum at C4-C5 (4.2 mm). Therefore, by the identification of this landmark, we can identify the distance between it and the nerve root to do adequate decompression and the distance between it and the vertebral artery to avoid its injury.

From the results of this work, the distance from the medial border of the foramen transverserum to the contra-lateral foramen increased from rostral to caudal direction. The average distances between tip of UP and vertebral foramen above were shortest at C2-C3 and longest at C5-C6. This is compatible with the results of Cooper and Heary et al., [6,11]. In all specimens, the VAs passed through the foramen transversarium of C6. Hong et al.,[14] reported that the VA enters the foramen transversarium of C6 in 94.9%. Civelek et al.,[4] also reported that the vertebral artery enters the foramen transversarium of C6 in 90%.

In the finding of the present study, the average height of the non-distracted disc space was minimum at C4-C5 (3.4 mm) and maximum at C5-C6 (4.6 mm) while the average height of the distracted disc spaces was minimum 8.6 mm at many levels and maximum at C3-C4 (8.8 mm). Pait et al.,[19] said that the height of the distracted disc space is important if arthrodesis is performed. The size graft is desirable in most cases because of loss of graft height during the bone maturation period.

Our results showed that the width of the disc space gradually increased from C2-C3 (22.8 (19.2 mm) to C6-C7 (28.7 mm). These agree with Pait et al.,[19] in that advances in radiological imaging, such as computed tomography and magnetic resonance imaging, may help in identifying anomalous or malpositioned vascular and/or bony structures leading to reduce the incidences of intraoperative mishaps.

CONCLUSION

This study of the anatomy of the anterior cervical spine was performed using formalin-fixed Egyptian cadaver specimens. These measurements provide the surgeon with essential data before doing any anterior cervical surgery. These measurements also provide guidelines for operating on the anterior cervical spine, facilitate adequate decompression of the neural elements, and increase the margin of safety and confidence of the operating surgeon. Although avoiding unfortunate injury is not always possible, an understanding of the location and relations among the anatomic features is the only safeguard against unwarranted damage.

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الملخص العربى
دراسة تشريحية فى المعالجة الأمامية للفقرات العنقية تحت المحور

بحث مقدم من:

د. يوسف حسين* ، د. عصام عبد الحميد**

الهدف من البحث :

أن معرفة العلاقات والقياسات التشريحية الأمامية للفقرات العنقية تحت المحور ضرورية لاداء جراحات ناجحة ويهدف هذا البحث إلى دراسة الوضع التشريحى وبعض القياسات الهامة للمنطقة العنقية للعمود الفقرى لتوضيح العلاقة بين الأعصاب الوعائية والعظام المحيطة .

الطرق والمواد المستخدمة :

لقد كانت القياسات على المنطقة العنقية لجثث الرجال المصريين البالغين وتضمنت الآتى :

المسافات بين الحدود المتجهة نحو خط المنتصف للعضلات العنقية الطويلة عند مستوى كل غضروف، سمك العضلة، المسافة بين الحد المتجهة نحو خط المنتصف للعضلة العنقية الطويلة والشريان الفقرى، عرض وإرتفاع كل غضروف عند المنتصف قبل إزالته، عرض وإرتفاع النتوء الضلعى، طول الشريان الفقرى بين النتؤات الضلعية، المسافة بين الحدود المتجهة نحو المنتصف للثقب العرضى والثقب المعاكس، عرض وإرتفاع التنوء الخطافى المسافة بين قمة النتوء الخطافى، المسافة بين قمة النتوء الخطافى والثقب العلوى بين الفقرات، المسافة بين قمة النتوء الخطافى والشريان الفقرى، إرتفاع الفراغ بين الفقرات بعد إزالة الغضروف، المسافة بين نهاية الجزء الخلفى المتجهة للمنتصف من النتوء الخطافى والشريان الفقرى وكذلك المسافة من الجزء الخلفى المتجهة للمنتصف من النتوء الخطافى إلى بداية جزر العصب .

النتـائـج :

ان أقصر مسافة بين الحد المتجهة نحو المنتصف للعضلة العنقية الطويلة والشريان الفقرى كانت عند الفقرتين الخامسة - السادسة. طول الشريان الفقرى المكشوف بين النتؤات الضلعية يزداد من الاتجاه الذيلى الى الاتجاه الجمجمى. كانت العضلة أكثر سمكاً عند الفقرتين الرابعة - الخامسة. أقصر مسافة بين قمة النتوء الخطافى والشريان الفقرى كانت عند الفقرتين السادسة - السابعة بينما أقصر مسافة بين قمة النتوء الخطافى والثقب العلوى بين الفقرات كانت عند الفقرتين الثانية - الثالثة. أقصر مسافة بين الجزء الخلفى المتجهة للمنتصف من النتوء الخطافى والشريان الفقرى كانت عند الفقرتين الثانية - الثالثة بينما الأطوال كانت بين الفقرتين الخامسة - السادسة. أقصر مسافة بين الجزء الخلفى المتجهة للمنتصف من النتوء الخطافى وجزر العصب كانت عند الفقرتين الثانية - الثالثة بينما الأطوال كانت بين الفقرتين الرابعة - الخامسة أن إرتفاع الغضروف قبل إزالته كان الأكثر بين الفقرتين الخامسة - السادسة بينما كان الأكثر إرتفاعاً بين الفقرتين الثالثة - الرابعة بعد الازالة. عرض النتوء الضلعى كان الاقصر عند الفقرة العنقية الثالثة والأطوال عند الفقرة السابعة. إرتفاع النتوء الضلعى كان الاقصر عند الفقرة السابعة والأطوال عند الفقرتين الخامسة والسادسة. القياسات الآتية تزداد من الاتجاه الجمجمى الى الاتجاه الذيلى وهى المسافات بين الحدود المتجهة نحو المنتصف للعضلات العنقية الطويلة، عرض الغضروف قبل الازالة، المسافة بين الحدود المتجهة نحو المنتصف للثقب العرضى والثقب المعاكس، عرض وإرتفاع النتوء الخطافى .

الخلاصـة

كل هذه القياسات السابقة تمد الجراح بالبيانات الضرورية قبل إجراء أى عملية جراحية فى الفقرات العنقية وذلك لتجنب إصابة الأعصاب الوعائية .