Int J Clin Exp Med 2016;9(7):14012-14017
www.ijcem.com /ISSN:1940-5901/IJCEM0026133

*Original Article*

# Application of structural autologous cervical laminae as bone graft in anterior cervical discectomy and fusion

Jia-Ming Liu*, Wei-Lai Tong*, Xu Xiong, Xuan-Yin Chen, Xin-Hua Long, Shan-Hu Huang, Yong Shu, Zhi-Li Liu

*Department of Orthopaedic Surgery, The First Affiliated Hospital of Nanchang University, Nanchang 330006, P. R. China. *Equal contributors and co-first authors.*

Received February 17, 2016; Accepted May 15, 2016; Epub July 15, 2016; Published July 30, 2016

**Abstract:** Background: Autograft bone is still the gold standard as fusion substrate in anterior cervical discectomy and fusion (ACDF). In patients underwent combined posterior laminectomy and anterior discectomy surgery, whether the resected structural cervical laminae are suitable for bone graft in ACDF during the surgery remains unclear. The purpose of this study is to evaluate if the height and area of the structural cervical laminae are large enough for bone graft in ACDF by computed tomography (CT) scan. Methods: Computed tomography scan of the cervical spine was performed in fifty adult cases. There were 25 males and 25 females with an average age of 30.4 years (range, 20-40 years). The axial and sagittal planes of the cervical spine were harvested for anatomical measurement. The heights of bilateral laminae from C3 to C7 were measured and the area of the triangle composed by bilateral laminae was computed. Also, the anterior, middle and posterior heights of the intervertebral space from C3 to C7 were measured and the area of inferior vertebral endplate was calculated. Then, the parameters of the laminae were compared to those of the corresponding vertebrae body. Results: The height of the cervical laminae in male ranged from 11.47 mm to 14.09 mm on the left side and from 11.52 mm to 14.08 mm on the right side from C3 to C7. In the female, the height of the laminae ranged from 10.57 mm to 13.07 mm on the left side and from 10.54 mm to 13.13 mm on the right side. The area of the laminae triangle ranged from 161.79 $mm^2$ to 183.87 $mm^2$ in the male and from 148.53 $mm^2$ to 155.89 $mm^2$ in the female from C3 to C7, with an average of 164.60 $mm^2$. The heights of the anterior, middle and posterior of the intervertebral space were from 4.30 mm to 4.77 mm, 5.55 mm to 6.25 mm and 3.88 mm to 4.03 mm, respectively. Significant differences were found between the heights of the laminae and the corresponding middle heights of intervertebral space ($P < 0.05$). From C3 to C7, the areas of the inferior vertebral endplate were from 209.01 $mm^2$ to 223.48 $mm^2$ with a mean value of 217.79 $mm^2$. The average ratio of the laminae triangle area to that of endplate was 75.58%. Conclusions: The height and area of the structural cervical laminae are adequate for bone graft in ACDF. Autologous structural cervical laminae represent a viable alternative to traditional fusion graft in patients underwent combined postero-anterior cervical surgery.

**Keywords:** Cervical laminae, anatomical measurement, anterior cervical discectomy and fusion, bone graft

## Introduction

Anterior cervical discectomy and fusion (ACDF) is an important procedure for the treatment of cervical spondylosis. Autologous bone is frequently utilized in this procedure to reconstruct the anterior column of the spine. Currently, the gold standard for fusion substrate is still the anterior iliac crest (AIC). However, bone graft harvested from AIC was associated with multiple complications [1-4]. Other autografts, such as fibula and rib have been reported to develop focal kyphosis and brought significant iatrogenic injury to the patients [5]. Thus, finding a new source of autograft bone is very useful in ACDF.

In patients with cervical spondylotic myelopathy, sometimes combined posterior laminectomy and anterior discectomy are necessary because of the spinal cord compressed both anteriorly and posteriorly. Whether the structural cervical laminae resected from posterior is suitable for bone graft in ACDF? It is still unclear.

The purpose of this study is to evaluate if the height and area of structural cervical laminae are adequate for bone graft in ACDF by measuring morphometric parameters of cervical laminae.


**Figure 1.** The measurement of the heights of bilateral cervical laminae (LH).

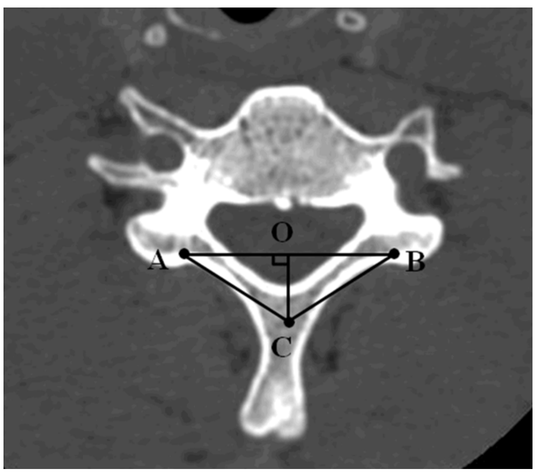


**Figure 2.** The linear parameters related to bilateral laminae. Points A and B are the intersections of the laminae and pedicles, Point C is the posterior junction of the bilateral laminae. Line OC is the distance from Point C to Line AB. The area of ΔABC is the area of the triangle composed by bilateral laminae.

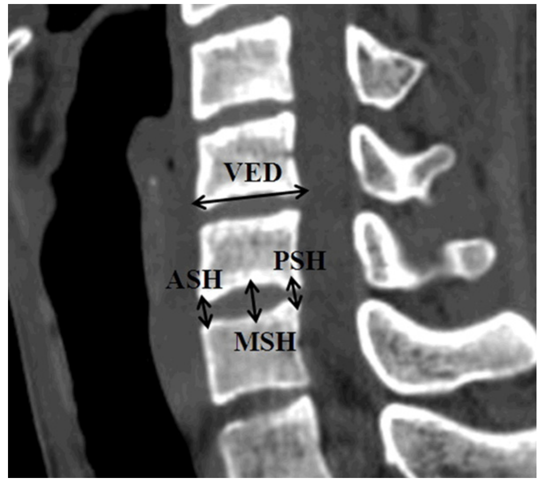


**Figure 3.** The measurement of intervertebral space height and the diameter of inferior vertebral endplate from C3 to C7. VED = the diameter of the inferior vertebral endplate. ASH, MSH, PSH = the heights of anterior, middle and posterior of the intervertebral space.

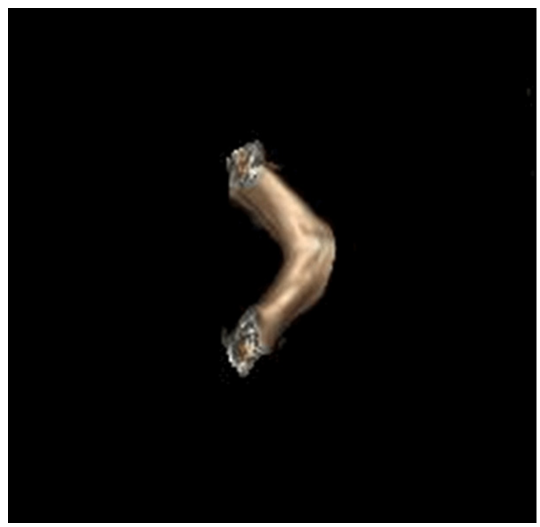

**Figure 4.** The 3D reconstruction CT of the cervical laminae, which was used as a bone graft in ACDF.

## Materials and methods

*Patient collection and measurement methods*

Fifty patients who received computed tomography (CT) scan because of neck pain were involved in the study. Written informed consent for participation in the study was obtained from all patients. The study protocol was ethically approved by the Human Research Ethics Committee of the hospital. There were 25 males and 25 females with an average age of 30.4 years (range, 20-40 years). None of the patients had any evidences of infectious, neoplastic, traumatic, or degenerative diseases involving the spine, or any evidences of congenital or developmental spinal malformation.

All the patients underwent CT scan (Toshiba Aquilion 64 CT, Japan) for the cervical spine. The axial and sagittal planes from C3 to C7 were obtained and the following parameters

**Table 1.** The heights of the bilateral cervical laminae from C3 to C7

| Vertebral | LH* of male (mm) | | | LH* of female (mm) | | | LH* of total patients (mm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Left | Right | Mean | Left | Right | Mean | Left | Right | Mean |
| C3 | 11.61±1.17 | 11.59±0.92 | 11.60±1.02 | 10.57±1.04 | 13.13±1.26 | 11.85±0.84 | 11.20±1.23 | 12.20±1.30 | 11.70±0.95 |
| C4 | 11.60±1.06 | 11.58±1.02 | 11.60±1.00 | 10.73±1.02 | 10.54±1.03 | 10.63±0.96 | 11.26±1.12 | 11.12±1.14 | 11.2±1.10 |
| C5 | 11.47±1.01 | 11.52±0.98 | 11.49±0.97 | 10.57±1.19 | 10.66±1.23 | 10.62±1.10 | 11.11±1.16 | 11.18±1.16 | 11.15±1.10 |
| C6 | 12.49±1.05 | 12.50±0.94 | 12.49±0.96 | 11.29±1.20 | 10.72±1.40 | 11.00±1.05 | 12.02±1.25 | 11.7±1.43 | 11.9±1.23 |
| C7 | 14.09±1.07 | 14.08±0.87 | 14.09±0.92 | 13.07±1.22 | 11.35±1.08 | 12.21±0.81 | 13.69±1.23 | 13.00±1.65 | 13.35±1.27 |

*LH, the height of the laminae.

**Table 2.** The heights of anterior, middle and posterior of the intervertebral space from C3 to C7

| Vertebral space | SH* of male (mm) | | | SH* of female (mm) | | | SH* of total patients (mm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | ASH# | MSH$^{\Delta}$ | PSH** | ASH# | MSH$^{\Delta}$ | PSH** | ASH# | MSH$^{\Delta}$ | PSH** |
| C3 | 4.26±0.53 | 5.45±0.59 | 3.90±0.62 | 4.94±0.52 | 6.02±0.48 | 3.96±0.59 | 4.53±0.62 | 5.67±0.61 | 3.92±0.60 |
| C4 | 4.47±0.63 | 5.83±0.59 | 3.97±0.49 | 4.10±0.65 | 5.12±0.51 | 3.75±0.64 | 4.32±0.66 | 5.55±0.65 | 3.88±0.56 |
| C5 | 4.78±0.43 | 5.90±0.49 | 4.10±0.72 | 4.34±0.75 | 5.52±0.63 | 3.92±0.57 | 4.61±0.60 | 5.76±0.58 | 4.03±0.67 |
| C6 | 4.33±0.81 | 5.99±0.67 | 3.99±0.92 | 4.27±0.77 | 5.58±0.66 | 3.85±0.74 | 4.30±0.79 | 5.83±0.69 | 3.94±0.85 |
| C7 | 5.12±0.54 | 6.51±0.38 | 4.18±0.75 | 4.25±0.63 | 5.84±0.50 | 3.58±0.61 | 4.77±0.71 | 6.25±0.54 | 3.94±0.75 |

*SH, the height of the intervertebral space. #ASH, the anterior height of the intervertebral space. $^{\Delta}$MSH, the middle height of the intervertebral space. **PSH, the posterior height of the intervertebral space.

**Table 3.** The area of the triangle composed by bilateral laminae and the inferior vertebral endplate from C3 to C7

| Vertebral | Area of triangle composed by bilateral laminae (mm$^2$) | | | Area of inferior vertebral endplate (mm$^2$) | | | Ratio (%) |
|---|---|---|---|---|---|---|---|
| | Male | Female | Mean | Male | Female | Mean | |
| C3 | 161.79±21.08 | 152.13±25.45 | 157.97±23.15 | 217.95±36.69 | 178.48±21.03 | 217.35±39.29 | 72.68 |
| C4 | 169.43±20.97 | 148.53±24.94 | 161.16±24.64 | 229.15±38.11 | 180.80±30.76 | 209.01±41.91 | 77.10 |
| C5 | 170.15±22.79 | 149.86±15.67 | 162.12±22.45 | 232.40±49.11 | 194.23±30.77 | 216.50±45.23 | 74.88 |
| C6 | 179.17±27.30 | 153.40±18.54 | 168.97±27.17 | 247.44±53.42 | 189.94±35.50 | 223.48±53.77 | 75.61 |
| C7 | 183.87±32.84 | 155.89±21.96 | 172.80±31.91 | 241.47±39.22 | 196.18±34.12 | 222.60±42.50 | 77.63 |

were measured: the heights of bilateral cervical laminae (LH) (**Figure 1**), the distance between the bilateral intersections of the laminae and pedicles (Line AB), the distance from the junction of bilateral laminae to the line connecting the intersection points which mentioned above (Line OC) (**Figure 2**), the heights of anterior, middle and posterior of the intervertebral space (ASH, MSH and PSH) and the diameter of inferior vertebral endplate (VED) from C3 to C7 (**Figure 3**). Intervertebral space heights were measured by a perpendicular line from the anterior, middle and posterior of one inferior cervical endplate to the superior endplate of the adjacent vertebral body. The diameters of the inferior vertebral endplate were measured from the antero-inferior point of the vertebral body to the postero-inferior point. Then, the area of the triangle composed by the bilateral laminae and the area of the inferior vertebral endplate from C3 to C7 were computed based on the data we measured.

During the surgery, the structural cervical laminae were implanted into the intervertebral space with the bilateral laminae perpendicular to the adjacent endplates and the junction toward posteriorly. Then, the local bones were packed into the laminae triangle. So, the area of the laminae triangle is supposed to be the area of the interbody bone graft fusion (**Figures 3**, **4**).

Measurements were conducted using Vitrea 2.0 workstation (Toshiba, Japan), accurate to 0.01 mm for linear data. Three of the authors performed the measurement independently (Long XH, Chen XY and Zhou YF). And the average values were calculated as the final results. The heights of the left laminae were compared to those right one, and the overall mean heights were calculated. In addition, the laminae heights were compared to the heights of the corresponding intervertebral space. And the area of the laminae triangles was compared to those of corresponding inferior vertebral endplate from C3 to C7.

*Statistical analysis*

The parameters measured in this study were expressed as mean values ± standard deviation. All the data were analyzed using SPSS statistical package 13.0 (SPSS Inc., Chicago, IL, USA). The heights of the left and right laminae were compared with the paired *Student's t*-tests. And the parameters between the laminae and the intervertebral space were compared with the unpaired *Student's t*-tests. $P < 0.05$ was considered as statistically significant.

## Results

Based on the measurement, the mean and standard deviation of each parameter was calculated from C3 to C7. The height of the cervical laminae in male ranged from 11.47 mm to 14.09 mm on the left side and from 11.52 mm to 14.08 mm on the right side from C3 to C7. No significant difference was found between the two sides ($P > 0.05$). In female, the height of the laminae ranged from 10.57 mm to 13.07 mm on the left side and from 10.54 mm to 13.13 mm on the right side. Also, there was no difference between the two sides ($P > 0.05$). In addition, no significant difference was noted between the male and female for laminae heights from C3 to C7 ($P > 0.05$) (**Table 1**). The anterior, middle and posterior heights of the cervical intervertebral space were from 4.30 mm to 4.77 mm, 5.55 mm to 6.25 mm and 3.88 mm to 4.03 mm, respectively (**Table 2**). Compared to the anterior and posterior space heights, the middle was the greatest one, with a significant difference ($P < 0.05$). The mean height of the laminae was greater than the middle height of corresponding intervertebral space ($P < 0.05$), with an average difference of 6.01 mm.

The area of the triangle composed by the bilateral laminae ranged from 161.79 $mm^2$ to 183.87 $mm^2$ in the male and from 148.53 $mm^2$ to 155.89 $mm^2$ in the female from C3 to C7. No statistical significant difference was found between the two groups ($P > 0.05$). For the inferior vertebral endplate, the areas were from 217.95 $mm^2$ to 247.44 $mm^2$ in the male and from 178.48 $mm^2$ to 196.18 $mm^2$ in the female. Also, there was no significant difference between male and female from C3 to C7 ($P > 0.05$) (**Table 3**). Compared the area of the laminae triangle to those of corresponding inferior vertebral endplates, no significant difference was detected between the two groups ($P > 0.05$). The mean ratio of the triangle area to the corresponding endplate area was 75.58%.

## Discussion

Since Cloward et al firstly introducing anterior cervical approach in the early of 1950s, ACDF has been a popular procedure for degenerative cervical spinal diseases [6-8]. And autologous iliac bone is considered to be the gold standard fusion substrate in ACDF. However, significant morbidity related to the graft harvest has been reported to be 10-39% [9], such as persistent pain and numbness, donor site infection, cosmetic defects and so on [1-4]. Allograft is an alternative to autograft for ACDF. However, there were also disadvantages related to allograft bone, such as transmission disease and other infectious agents. In addition, immunogenic incompatibility was another important problem with allograft [10]. And the incidence of nonunion in the allograft group was higher than that of autograft [11]. Though various synthetic materials have been used for interbody grafts in anterior cervical fusion recently [12], benefits must be weighed against the significant increased cost of synthetics as well as potentially poor osteoinductivity and the limited contact area available for bony fusion. Thus, we introduced a new source of autograft structural bone for ACDF in this study.

In patients with severe cervical spondylotic myelopathy, the compressions to the spinal cord may come from both anterior and posterior. Sometimes, combined posterior laminectomy and anterior discectomy surgery will be necessary for these patients. When performing posterior laminectomy firstly to decompress the spinal cord, whether the structural laminae could be used as bone graft in ACDF? To our knowledge, few studies have reported about this.

In the present study, the average height of the bilateral cervical laminae was 6.01 mm higher than the middle height of corresponding intervertebral space according to the measurement. In a study conducted by An et al [13], it indicated that the ideal cervical graft thickness appeared to be directly related to the preoperative baseline disc height, and an interbody graft of 2 mm above baseline thickness was most appropriate. Olsewski et al [14] also found that cervical disc space distraction 2-3 mm in ACDF was desirable based on cadaveric studies. In this study, we found that the cervical laminae were significant higher than those corresponding intervertebral space. The actual size of laminae may be decreased after manipulating the cortical portion of upper and lower margin for inserting into intervertebral space during the surgery. However, we usually just resect about 1 mm cortical bone from the upper and lower margin of the laminae and the height of the laminae is still higher than those corresponding intervertebral space. Therefore, we believe that the height of the structural cervical laminae will fully meet the need of bone graft in ACDF.

When cervical laminae were inserted into the intervertebral space during the surgery, we packed the laminae triangle with local bone chips and spinous process. So, the area of the triangle is supposed to be the area of the interbody bone graft fusion. Based on the measurement, the area of the triangle was from 157.97 $mm^2$ to 172.80 $mm^2$ (**Table 3**). The mean ratio of the triangle area to the corresponding area of the inferior vertebral endplate was 75.58%. Although no study has reported how much the area of the bone graft contacting with the superior and inferior vertebral endplate was optimal for bony fusion, we think that the area of the triangle of the laminae is adequate for interbody bone graft fusion.

There are also several limitations in this study, including the absence of a cadaveric study and a small sample size. Furthermore, this procedure is just performed in patients needing combined posterior laminectomy and anterior discectomy surgery. And the effectiveness of using structural cervical laminae in ACDF in patients with cervical spondylosis is not clear. So, further research and a large sample size is needed to make sure the safety and effectiveness of the laminae autograft.

Based on the measurements, the height and area of the structural cervical laminae are adequate for bone graft in ACDF. It indicated that structural cervical laminae could be a viable material for bone graft in patients who underwent combined posterior laminectomy and anterior discectomy surgery.

### Acknowledgements

This work is supported by the Department of Science and Technology Program Funds of Jiangxi Province, P.R. China (No. 20123BBG70245, 20123BBG70037) and the Natural Science Foundation of Jiangxi Province, P.R. China (No. 20142BAB215046 and No. 20151BAB215026).

### Disclosure of conflict of interest

None.

**Address correspondence to:** Dr. Zhi-Li Liu, Department of Orthopaedic Surgery, The First Affiliated Hospital of Nanchang University, No. 17 Yongwaizheng Street, Nanchang 330006, Jiangxi Province, P. R. China. Tel: 0086-791-88693201; Fax: 0086-791-88693201; E-mail: zgm7977@163.com

### References

[1] Silber JS, Anderson DG, Daffner SD, Brislin BT, Leland JM, Hilibrand AS, Vaccaro AR, Albert TJ. Donor site morbidity after anterior iliac crest bone harvest for single-level anterior cervical discectomy and fusion. Spine 2003; 28: 134-139.

[2] Sasso RC, LeHuec JC, Shaffrey C. Iliac crest bone graft donor site pain after anterior lumbar interbody fusion: a prospective patient satisfaction outcome assessment. J Spinal Disord Tech 2005; 18 Suppl: S77-S81.

[3] Arrington ED, Smith WJ, Chambers HG, Bucknell AL, Davino NA. Complications of iliac crest bone graft harvesting. Clin Orthop Relat Res 1996; 329: 300-309.

[4] Porchet F, Jaques B. Unusual complications at iliac crest bone graft donor site: experience with two cases. Neurosurgery 1996; 39: 856-859.

[5] Jagannathan J, Shaffrey CI, Oskouian RJ, Dumont AS, Herrold C, Sansur CA, Jane JA. Radiographic and clinical outcomes following single-level anterior cervical discectomy and allograft fusion without plate placement or cervical collar. J Neurosurg Spine 2008; 8: 420-8.

[6] Smith GW, Robinson RA. The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. J Bone Joint Surg Am 1958; 40-A: 607-24.

[7] Cloward RB. The anterior approach for removal of ruptured cervical disks. J Neurosurg 1958; 15: 602-17.

[8] Song KJ, Choi BY. Current concepts of anterior cervical discectomy and fusion:a review of literature. Asian Spine J 2014; 8: 531-9.
[9] Heneghan HM, McCabe JP. Use of autologous bone graft in anterior cervical decompression: morbidity & quality of life analysis. BMC Musculoskelet Disord 2009; 10: 158.
[10] Grauer JN, Beiner JM, Kwon BK, Vaccaro AR. Bone graft alternatives for spinal fusion. Bio Drugs 2003; 17: 391-394.
[11] Samartzis D, Shen FH, Matthews DK, Yoon ST, Goldberg EJ, An HS. Comparison of allograft to autograft in multilevel anterior cervical discectomy and fusion with rigid plate fixation. Spine J 2003; 3: 451-9.
[12] Zdeblick TA, Phillips FM. Interbody cage devices. Spine 2003; 28 (Suppl): S2-7.
[13] An HS, Evanich CJ, Nowicki BH, Haughton VM. Ideal thickness of Smith-Robinson graft for anterior cervical fusion. A cadaveric study with computed tomographic correlation. Spine 1993; 18: 2043-7.
[14] Olsewski JM, Garvey TA, Schendel MJ. Biomechanical analysis of facet and graft loading in a Smith-Robinson type cervical spine model. Spine 1994; 19: 2540-4.