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Evaluation of risk factors affecting development of hinge fracture complications related to open-door cervical laminoplasty technique

Open-door servikal laminoplasti tekniğine bağlı hinge fraktürü (menteşe kırığı) komplikasyonu gelişmesini etkileyen risk faktörlerinin değerlendirilmesi

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ABSTRACT

Aim: Open-door cervical laminoplasty is the standard surgical option for patients with multipl levels cervical myelopathy. In this surgical technique, while linear laminectomy is performed on one side of the lamina, bone is drilled to form a hinge on the opposite side. Hinge fractures may occur on the other side while lifting the linear laminectomy side. Our study aimed to examine possible risk factors for preventing these fractures.

Materials and Methods: The patients' files, radiological images, and laboratory results who underwent cervical laminoplasty between 2013-2018 were retrospectively analyzed.

Results: A total of 78 patients, 54 males and 24 females, were included in the study. The mean age of the patients was 57.8±11.6 years. The mean modified Japanese Orthopedic Association (JOA) cervical myelopathy scores of the patients before the operation were 16.2±2.1. When the pre-operative blood Ca values were examined, the mean value was 9.3±0.5 mg/dl. The mean Pavlov ratio of the patients was 0.7±0.2. Laminas were opened from the right side in 26 cases and from the left side in 52 cases. A total of 304 laminae were opened. In post-operative control cervical CTs, 42 patients had lamina hinge fractures, and the number of patients without hinge fracture was 36. There were 89 fractures in total at the lamina level. When post-operative cervical tomography images were examined, the mean opening angle (OA) of the laminas was 30.6±8.9 degrees. The opening angle of the lamina was determined to affect the hinge fracture significantly. While OA was 32.3±9 degrees in patients with lamina hinge fracture, it was found to be 28.7±8.3 in patients without fractures ($p < 0.05$).

Conclusion: During open-door cervical laminoplasty, the excessive opening angle of the lamina increases the possibility of hinge fractures. Pre-operative necessary measurements will reduce the risk of hinge fractures during surgery. This evaluation will reduce the risk of complications during the operation and increase patient comfort in the post-operative period.

Keywords: Cervical laminoplasty, hinge fracture, risk factors.

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ÖZ

Amaç: *Open-door servikal laminoplasti multipl seviye servikal myelopatisi olan hastalar için standart cerrahi seçenektir. Cerrahide laminanın bir tarafına lineer laminektomi yapılırken, karşı tarafa menteşe halini alacak şekilde kemik drillemesi yapılır. Lineer laminektomi yapılan taraf kaldırılırken diğer tarafta menteşe kırıkları meydana gelebilir. Bu kırıkların oluşmaması için olası risk faktörlerini incelemeyi amaçladık.*

Gereç ve Yöntemler: *2013-2018 yılları arasında open-door servikal laminoplasti operasyonu geçiren olguların dosyaları, radyolojik görüntüleri, laboratuvar sonuçları retrospektif olarak incelendi.*

Bulgular: *Çalışmaya opere edilen 54 erkek, 24 kadın olmak üzere 78 hasta dahil edildi. Hastaların yaş ortalaması 57,8 ± 11,6 idi. Operasyon öncesi hastaların Modifiye JOA (Japanese Orthopedic Association) servikal miyelopati skorları 16,2 ± 2,1 olarak geldi. Operasyon öncesi kan Ca^{++} değerlerine bakıldığında 9,3 ± 0,5 mg/dl idi. Hastaların Pavlov oranı ortalaması 0,7 ± 0,2 idi. Laminalar 26 olguda sağ taraftan, 52 olguda sol taraftan açıldı. Toplam 304 lamina açıldı. Operasyon sonrası çekilen kontrol servikal BT'lerde 42 hastada lamina menteşe kırığı vardı. Menteşe kırığı olmayan hasta sayısı 36 idi. Toplamda 89 lamina seviyesinde kırık vardı. Cerrahi sonrası çekilen servikal BT'ler incelendiğinde laminaların açılma açısı (OA) ortalaması 30,6 ± 8,9 derece olarak ölçüldü. Lamina açılma açısının menteşe kırığına anlamlı ölçüde etki ettiği gözlendi. Lamina menteşe kırığı olan hastalarda OA 32,3 ± 9 (p<0,05) derece iken, olmayan hastalarda OA ortalama açısı 28,7 ± 8,3 (p<0.05) olarak bulundu.*

Sonuç: *Open-door servikal laminoplasti sırasında lamina açılma açısının fazlalığı menteşe kırıkları oluşması olasılığını artırmaktadır. Operasyon öncesi gerekli ölçümlerin yapılması ameliyat sırasında menteşe kırıklarının meydana gelme riskini azaltacaktır. Bu da hem operasyon sırasında komplikasyon riskini azaltacak hem de ameliyat sonrası dönemde hasta konforunu artıracaktır.*

Anahtar Sözcükler: *Servikal laminoplasti, menteşe kırıkları, risk faktörleri.*

INTRODUCTION

Open-door cervical laminoplasty is an operation that has become the standard surgical option for patients with single-level or multiple-level cervical myelopathy (1). The basic principle of surgery is to perform a linear laminectomy on one side of the lamina while creating a hinge-shaped bone deformation on the other side (2, 3). After the laminectomy side is lifted to enlarge the cervical canal, it is aimed to preserve the opening with the mini plate and screw support. Fracture of the other side, called as "hinge", is a technical complication during this procedure (4, 5). It has been reported in various studies that this complication may be associated with neck pain, shoulder pain, and nerve compression (4-6). However, risk factors for hinge fractures remain uncertain.

This study aims to determine the possible risk factors of hinge fracture that may occur during cervical laminoplasty and what should be considered in terms of pre-operative predictability.

MATERIALS and METHODS

Patients who referred to our clinic with symptoms of single or multiple level cervical myelopathies between 2013 and 2018 and operated with the open-door laminoplasty method by the same surgical team were included in the study. Radiological images, patient files, and laboratory results of the patients were analyzed retrospectively.

The patients had routine neurological examinations before the operation and Modified Japanese Orthopedic Association (JOA) cervical myelopathy scores were calculated. In this scoring, upper and lower extremity motor dysfunction, upper extremity sensory dysfunction, and sphincter dysfunction were evaluated. Pre-operative routine blood tests of the patients were performed, and blood calcium (Ca) values were recorded.

In order to determine the amount of cervical spinal canal stenosis in the patients to be operated on, Pavlov values were calculated by dividing the sagittal diameter of the cervical spinal canal to the vertebral body in lateral radiographs, and the average values were obtained. Values below 0.8 were accepted as cervical stenosis.

A standard cervical posterior approach was used for open-door laminoplasty (7). Segment

numbers were correlated with spinal cord compression length. First, a linear laminectomy was performed to the lateral mass and lamina junction on the lamina side to be lifted. Ligamentum flavum was separated by Kerrison rongeur. For the opposite side, the same junction was drilled with a 2 mm burr. The dorsal cortex was removed, and the ventral cortex was thinned. The lamina was raised from the side to be lifted, and the plate-screw system was placed for each level to protect the opening. At this stage, the ventral cortex on the hinge side was tried to be preserved. The click sound coming from the hinge side while lifting the lamina was considered a hinge fracture.

After the operation, the patients were followed up with a neck collar, and cervical tomography (CT) was taken within 24 hours post-operatively using 1.5 mm axial slices as the imaging method. Hinge fractures and their levels were determined in axial images. The places where the ventral cortex did not show continuity were accepted as hinge fractures.

The opening angle (OA) of each opened lamina was measured and averaged on post-operative CT scans using the method presented by Uematsu et al. (8) (Figure-1).

The Statistical Package for the Social Sciences (SPSS) 24 program analyzed the study data. When comparing two independent groups, the Independent-Samples T-test in the presence of a continuous variable and Pearson's Chi-Square test in the presence of categorical variables were used. Logistic Regression test measured the effect of factors on fracture formation as the multivariate analysis. Quantitative data were presented in the tables as mean ± standard deviation (std), and categorical data were expressed as number (n) and percentages (%). The data were analyzed at a 95% confidence level, and the p-value of less than 0.05 was considered significant.

RESULTS

In the study, a total of 78 operated patients, 54 (69.2%) males and 24 (30.8%) females, were included. The mean age of the patients was 57.8±11.6 years (range 26 to 90). Modified JOA cervical myelopathy scores measured pre-operatively during the routine neurological examinations of the patients (9) were calculated as 16.2±2.1. When the pre-operative blood Ca values of the patients were examined, the mean value was 9.3±0.5 mg/dl (normal value range 8.5-10.5 mg/dl) (Table-1). The mean value of the Pavlov ratio, determined as the rate of cervical spinal canal stenosis calculated on lateral radiographs of the patients (Figure-2) (10), was 0.7±0.2.

Laminas were opened from the right side in 26 (33.3%) cases and from the left side in 52 (66.7%) cases. In 78 patients, a total of 304 laminae were opened (with an average of 3.89 laminae per patient), and the levels of opened lamina were 2 for C2, 58 for C3, 73 for C4, 77 for C5, 76 for C6, and 18 for C7 (Table 2).

In post-operative control cervical CTs, 42 (53.8%) patients had lamina hinge fractures. In total, there were 89 lamina level fractures (with an average of 2.11 laminae per patient). While the levels of the fractured laminae were C3 for 12 laminae, C4 for 21 laminae, C5 for 27 laminae, C6 for 22 laminae, and C7 for seven laminae, no fractures were found at the C2 lamina level (Table-2).

When the post-operative cervical tomography images were examined, it was observed that the mean opening angle (OA) of the laminas was 30.6 ± 8.9 degrees. While OA was 32.3 ± 9 degrees in patients with lamina hinge fracture, the mean angle of OA was found as 28.7 ± 8.3 ($p < 0.05$) in patients without lamina hinge fracture (Table-3).

When independent risk factors such as age, gender, JOA, blood Ca level, Pavlov ratio, and the side where the lamina was lifted were examined, it was observed that the hinge fracture was not statistically correlated with these variables (Table-3).

A multivariate analysis was performed to examine the relationship between hinge fractures and predictable risk factors. In this analysis, it was determined that OA had a significant effect on hinge fracture formation (OR:1.055; $p < 0.05$; % 95 CI: 1.005-1.120) (Table-4).

Table-1. Characteristics of the patients.

Feature	Value
Age (years)	57.8 ± 11.6
Gender	
Male	54 (69.2%)
Female	24 (30.8%)
Side	
Left	52 (66.7%)
Right	26 (33.3%)
OA (degrees)	30.6 ± 8.9
JOA	16.2 ± 2.1
Pavlov's Ratio	0.7 ± 0.2
Ca Level	9.3 ± 0.5
Hinge Fracture	
Yes	42 (53.8%)
No	36 (46.2%)

OA: Opening Angle, JOA: Japanese Orthopedic Association

Table-2. Relationships of opened laminae levels with the fractures.

	C2	C3	C4	C5	C6	C7	Total	p value
Number of fractured hinges	0	12	21	27	22	7	89	0,35
Number of opened laminae	2	58	73	77	76	18	304	

Pearson's Chi Square Test

Table-3. Relationships of features with the fracture status.

Feature	Patients Without Hinge Fracture	Patients With Hinge Fracture	p value
Age (years)	57.1 ± 12.2	58.3 ± 11.2	0.65
OA (degrees)	28.7 ± 8.3	32.3 ± 9	**<0.05**
JOA	16.1 ± 1.9	16.3 ± 2.2	0.79
Ca Level	9.4 ± 0.5	9.3 ± 0.6	0.45
Pavlov's Ratio	0.7 ± 0.2	0.6 ± 0.1	0.13
Gender			
Male	23	31	0.24
Female	13	11	
Side			
Left	23	29	0.40
Right	13	13	

Independent-Samples t test for comparison of continuous variables,
Pearson's Chi Square test for comparison of categorical variables

Table-4. Multivariate analysis of the impacts of variables on hinge fractures.

Variable	B	OR	p value	95,0% CI for Exp(B)	
				Lower	Upper
Age	,004	1,004	0.85	,964	1,046
Gender	-,354	,702	0.51	,242	2,037
Side	,101	1,106	0.85	,368	3,329
OA	,054	1,055	**<0.05**	1,005	1,120
JOA	,052	1,053	0.68	,823	1,347
Ca Level	-,470	,625	0.31	,253	1,545
Pavlov's Ratio	-1,928	,145	0.28	,005	4,674

Logistic Regression

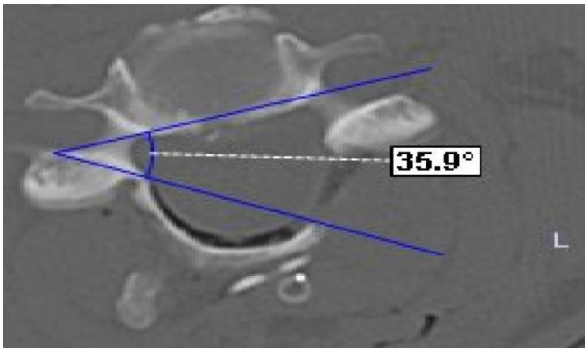

Figure-1. Opening angle.

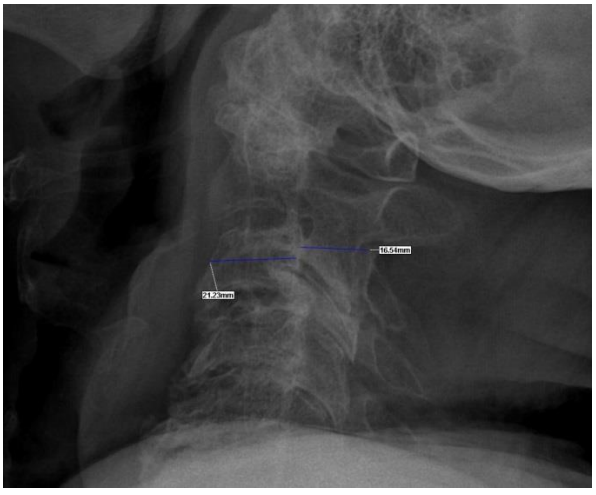

Figure-2. Pavlov ratio.

DISCUSSION

Cervical open-door laminoplasty is a surgical option for patients with cervical myelopathy. During surgery, one side of the lamina is thinned as a hinge, while the other side is lifted with linear laminectomy, and the pressure in the spinal canal is relieved. It is common for the hinge side to fracture during surgery. These fractures can be detected by imaging methods and may cause shoulder and neck pain in the post-operative period (5). In order to avoid post-operative negativity, risk factors that may predispose to hinge fracture should be determined before surgery. The opening angles of the laminas during surgery are among the issues that can affect the hinge fracture the most.

The study of Cho et al. examining the clinical and radiological results of hinge fractures in cervical laminoplasty found that age, smoking history, and gender were not risk factors for hinge fractures (11). Age and gender were not considered as risk factors in the series of 36 patients with cervical laminoplasty performed by Lee et al. (12). Age and gender were not risk factors for hinge fractures in our study, either.

In the study conducted by Park et al., in which JOA and Neck Disability Index (NDI) scores were examined, no significant difference was found between patients with and without fractured hinges (13). While the study conducted by Lee et al. also supported this study in terms of both scores affecting the outcomes (12), our study is compatible in terms of the JOA score.

Blood calcium level is vital for the mechanical strength of the bone. Bone calcium acts as a reservoir in the case of calcium deficiency (14). There was no study in the literature showing the relationship between hinge fractures that occurred during open-door cervical laminoplasty surgery and blood calcium. Our study concluded that blood calcium levels were not a risk factor in the post-operative period of the patients whose blood calcium levels were noted before the operation and had hinge fractures. There was no significant difference between the groups with and without hinge fractures.

One of the ratios showing the degree of stenosis of the cervical spinal canal is the Pavlov ratio (10). In the literature, this ratio has generally been compared before and after the operation. In the study performed by Zhang et al., in which cervical laminoplasty methods were compared surgically, no significant difference was found between post-operative Pavlov rates (15). Pavlov ratio was found to be an independent risk factor for blood loss in the study of Meng et al., where they investigated the risk factors associated with blood loss during cervical laminoplasty (16). In our study, in which the pre-operative Pavlov ratio was considered as an independent risk factor for hinge fracture, it was observed that this ratio did not affected on hinge fracture.

In our study, when the sides of the hinge fractures were evaluated, it was seen that the fracture rate on the right side was higher in the lamina lifted from the left side. This result was attributed to the surgical team's more right-handed use and the use of burr while forming a hinge withstanding on the right side of the patient in the prone position.

The study conducted by Lee et al., in which 135 laminae were evaluated, found no significant difference between the patients with and without hinge fracture in the opening angle (OA) of the laminas (12). In a study examining risk factors in hinge fractures, the lamina angle was measured, and the lamina angle over 51 degrees was found to be significant in terms of hinge fracture (17). In a study by Hur et al. conducted on 80 patients and 270 laminae, it was stated that a wide opening angle could make the hinge grooves more stressful, and this condition may increase fractures (18). Our study observed that fracture rates increased as the degree of lamina opening angle increased. The mean value of the lamina opening angle of patients with hinge fractures was calculated to be 32.3 ± 9 degrees. It was predicted that as this value increases, the number of broken hinge fractures might increase.

CONCLUSION

In our study, the risk factors affecting hinge fracture, which is a common condition in open-door cervical laminoplasty surgery, were analyzed. Demographic data such as age, gender, and Pavlov ratio were observed not to be risk factors. It was determined that the lamina opening angle was a significant risk factor. We think that the measurements to be made before the operation will minimize this complication.

Conflict of interest: The authors declare that there is no conflict of interest.

References

1. Chen H, Liu H, Zou L, Li T, Gong Q, Song Y, et al. Effect of Mini-plate Fixation on Hinge Fracture and Bony Fusion in Unilateral Open-door Cervical Expansive Laminoplasty. Clin Spine Surg. 2016;29(6):E288-95.
2. Byard RW, Langlois N, Gilbert JD. Positive "water test"-an external indicator of base of skull hinge-ring fracture. J Forensic Sci. 2010;55(2):519-20.
3. Takeuchi R, Ishikawa H, Kumagai K, Yamaguchi Y, Chiba N, Akamatsu Y, et al. Fractures around the lateral cortical hinge after a medial opening-wedge high tibial osteotomy: a new classification of lateral hinge fracture. Arthroscopy. 2012;28(1):85-94.
4. Hirabayashi K, Satomi K. Operative procedure and results of expansive open-door laminoplasty. Spine (Phila Pa 1976). 1988;13(7):870-6.
5. Satomi K, Nishu Y, Kohno T, Hirabayashi K. Long-term follow-up studies of open-door expansive laminoplasty for cervical stenotic myelopathy. Spine (Phila Pa 1976). 1994;19(5):507-10.
6. Hosono N, Yonenobu K, Ono K. Neck and shoulder pain after laminoplasty. A noticeable complication. Spine (Phila Pa 1976). 1996;21(17):1969-73.
7. Steinmetz MP, Resnick DK. Cervical laminoplasty. Spine J. 2006;6(6 Suppl):274S-81S.
8. Uematsu Y, Tokuhashi Y, Matsuzaki H. Radiculopathy after laminoplasty of the cervical spine. Spine (Phila Pa 1976). 1998;23(19):2057-62.
9. Yonenobu K, Abumi K, Nagata K, Taketomi E, Ueyama K. Interobserver and intraobserver reliability of the japanese orthopaedic association scoring system for evaluation of cervical compression myelopathy. Spine (Phila Pa 1976). 2001;26(17):1890-4; discussion 5.
10. Chen H, Liu H, Deng Y, Gong Q, Li T, Song Y. Multivariate Analysis of Factors Associated With Axial Symptoms in Unilateral Expansive Open-Door Cervical Laminoplasty With Miniplate Fixation. Medicine (Baltimore). 2016;95(2):e2292.

11. Cho SH, Lee JH, Chough CK, Joo WI, Park HK, Lee KJ, et al. Hinge Fracture during Cervical Open-door Laminoplasty: Does it Affect Clinical and Radiographic Outcomes? Korean J Spine. 2014;11(2):45-51.
12. Lee DH, Kim H, Lee CS, Hwang CJ, Cho JH, Cho SK. Clinical and radiographic outcomes following hinge fracture during open-door cervical laminoplasty. J Clin Neurosci. 2017;43:72-6.
13. Park YK, Lee DY, Hur JW, Moon HJ. Delayed hinge fracture after plate-augmented, cervical open-door laminoplasty and its clinical significance. Spine J. 2014;14(7):1205-13.
14. Nordin BE. Calcium and osteoporosis. Nutrition. 1997;13(7-8):664-86.
15. Zhang X, Zhang Y, Duan D, Xie H. A Novel Drill Navigation Template Combines Preoperative Simulation in Expansive Open-Door Laminoplasty. World Neurosurg. 2018;118:e758-e65.
16. Meng Y, Wang X, Chen H, Hong Y, Wu T, Wang B, et al. Risk Factors for Significant Intraoperative Blood Loss During Unilateral Expansive Open-Door Cervical Laminoplasty for Cervical Compressive Myelopathy. World Neurosurg. 2018;114:e1253-e60.
17. Lee JH, Chough CK. Risk Factors for Hinge Fracture Associated with Surgery Following Cervical Open-Door Laminoplasty. Korean J Neurotrauma. 2018;14(2):118-22.
18. Hur JW, Park YK, Kim BJ, Moon HJ, Kim JH. Risk Factors for Delayed Hinge Fracture after Plate-Augmented Cervical Open-Door Laminoplasty. J Korean Neurosurg Soc. 2016;59(4):368-73.