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ORIGINAL STUDY

Is OPLL-induced canal stenosis a risk factor of cord injury in cervical trauma ?

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The purpose of this study is to identify the relationship between trauma severity and the degree of cord injury in patients with ossification of posterior longitudinal ligament (OPLL). Four-hundred-one patients were classified into Group A (OPLL(+)), Group B (spinal stenosis (+) and OPLL(-)), and Group C (OPLL (-) and spinal stenosis(-)). Trauma severity and neurological injury severity were compared according to presence of OPLL and spinal stenosis. OPLL was associated with a higher incidence of neurological injury with statistical significance ($p = 0.002$), whereas spinal stenosis did not ($p = 0.408$). With Group B+C (no OPLL group) in M (minimal) trauma group as baseline, Group A in M trauma group showed about 5 times, and Group A in S (severe) trauma group showed about 16 times as many cord injury. Patients with OPLL more frequently sustained spinal cord injury from minimal trauma.

Key word : ossification of posterior longitudinal ligament ; spinal cord injury ; incidence ; injury severity score.

INTRODUCTION

Ossification of posterior longitudinal ligament (OPLL) chiefly occurs in Japan, Korea and China (*4,6,16*) and mainly involves cervical spine. Posterior longitudinal ligament is ossified into the spinal canal and protrudes to compress spinal cord or nerve root, which consequently causes various neurological symptoms. These symptoms may slowly develop as paraplegia or quadriplegia, causing permanent neurological deficit (*13*).

Several studies have evaluated spinal stenosis as a potential contributor to severe cord injury in low-energy trauma (*8,12*). However, there is no objective definition of minor and major trauma in these reports. We used injury severity score (ISS) to stage the extent of injury (*1*). The maximum score of ISS is 75 points, and point ranges of 0-7, 8-16, 17-25 and > 26 are considered as minor trauma, moderate trauma, severe trauma, and very severe trauma, respectively (*11*).

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It is generally accepted that surgical treatment is not mandatory for cord compression from ossification of posterior longitudinal ligament (OPLL) in the absence of relevant neurological symptoms (*12*). However, clinicians in the East Asian countries often manage patients with OPLL who sustain permanent neurological injury such as complete cord injury despite low-energy trauma. Patients with OPLL seem to experience more severe neurological injury compared to patients without OPLL, given similar trauma severity. So far, there is no report on the relationship between trauma severity and neurological injury severity in patients with OPLL-induced canal stenosis.

Therefore, the authors assessed the severity of neurological injury in patients with OPLL, examined the incidence of OPLL in patients who had undergone surgical treatment due to cervical spine trauma, and compared trauma severity and neurological injury severity according to presence of OPLL.

MATERIAL AND METHODS

This study included 401 patients, who had undergone surgical treatments for cervical spine trauma accompanying neurological injury from May, 2000 to January, 2012. Medical records and radiologic studies were reviewed retrospectively. The mean age was 52.7 years (ranging from 19 to 81 years), and there were 316 males (79%) and 85 females (21%).

The patients were assigned into Group A (patients with OPLL, the 'OPLL group'), Group B (patients with spinal stenosis in the absence of OPLL, the 'Stenosis group') and Group C (patients without both OPLL and spinal stenosis, the 'No OPLL and Stenosis group').

OPLL was diagnosed with computed tomography (CT), and spinal stenosis was diagnosed when Pavlov ratio was less than 0.8. Neurological injury severity was divided into spinal cord injury and non-spinal cord injury. Trauma severity was assessed using the injury severity score (ISS) (1). The maximum score of ISS is 75 points, and point ranges 0-7, 8-16, 17-25 and greater than 26 are considered as minor trauma, moderate trauma, severe trauma and very severe trauma, respectively (11). The authors defined Group M (minimal) to include minor and moderate trauma and Group S (severe) to include severe and very severe trauma (Table I).

Groups A, B, and C included 52 patients (12.8%), 223 patients (64%) and 126 patients (36%), respectively. Groups M and S included 336 patients (84%) and 65 patients (16%), respectively. Group A has 46 patients (88.5%) in Group M and 6 patients (11.5%) in Group S. Group B has 186 patients (83.4%) in Group M and 37 patients (16.6%) in Group S. Group C has 104 patients (82.5%) in Group M and 22 patients (17.5%) in Group S. Group B+C (without OPLL) has 290 patients (83.1%) in Group M and 59 patients (16.9%) in Group S (Table I). There were no statistically significant differences in age, gender, and ISS across the groups (Fisher's exact test, $p = 1.000$, $p = 0.772$, $p < 0.001$).

Trauma severity and neurological injury severity were compared according to the presence of OPLL and spinal stenosis (Table II). Fisher's exact test and multiple regression analysis were used for statistical analysis.

RESULTS

1. Incidence of spinal cord injury according to absence/presence of OPLL and spinal stenosis

Group A (OPLL group) included 21 patients (40.4%) with spinal cord injury and 31 patients (59.6%) without spinal cord injury. Group B (Stenosis group) included 46 patients (20.6%) with spinal cord injury and 177 patients (79.4%) without spinal cord injury. In case of Group C (No OPLL and Stenosis group), there were 26 patients (20.6%) with spinal cord injury and 100 patients (79.4%) without spinal cord injury. Group B+C (No OPLL) included 72 patients (20.6%) with spinal cord injury and 277 patients (79.4%) without spinal cord injury (Table II). In comparison according to absence/presence of OPLL, the incidence of spinal cord injury was higher for Group A than for Group B+C with statistical significance (Fisher's exact test, $p = 0.003$). In comparison according to absence/presence of spinal stenosis (Group B vs. Group C), differences in spinal cord did not reach statistical significance between the groups ($p = 0.454$, Table II). In multiple regression analysis, OPLL was associated with higher incidence of neurological injury with statistical significance (multiple regression analysis, cruded OR 2.606, 95% CI 1.414-4.804, Adjusted OR 4.024, 95% CI 2.030-7.976), whereas spinal stenosis was not (Cruded OR 1.236, 95% CI 0.749-2.040, $p = 0.408$, Table III).

Table I. — Spinal cord injury according to trauma severity

		OPLL*		OPLL(-)				Toal
				Spinal stenosis		No stenosis		
Number		52		223		126		401
ISS** mild	None	2	100.0%	31	100.0%	32	100.0%	
	Cord injury	0	0.0%	0	0.0%	0	0.0%	
	Total	2		31		32		65
ISS moderate	None	27	61.4%	135	87.1%	60	83.3%	
	Cord injury	17	38.6%	20	12.9%	12	16.7%	
	Total	44		155		72		271
M group (ISS mild, moderate)	None	29	63.0%	166	89.2%	92	88.5%	
	Cord injury	17	37.0%	20	10.8%	12	11.5%	
	Total	46		186		104		336
ISS severe	None	2	40.0%	11	31.4%	8	36.4%	
	Cord injury	3	60.0%	24	68.6%	14	63.6%	
	Total	5		35		22		62
ISS very severe	None	0	0.0%	0	0.0%	0		
	Cord injury	1	100.0%	2	100.0%	0		
	Total	1		2		0		3
S group (ISS severe, very severe)	None	2	33.3%	11	29.7%	8	36.4%	
	Cord injury	4	66.7%	26	70.3%	14	63.6%	
	Total	6		37		22		65

*OPLL : Ossification of Posterior Longitudinal Ligament.
**ISS : Injury severity score.

2. Incidence of spinal cord injury according to absence/presence of OPLL and trauma severity

In cases of minimal (M group) trauma, Group A (OPLL group) included 29 patients (63%) without spinal cord injury and 17 patients (37%) with spinal cord injury. Group B (Stenosis group) included 166 patients (89.2%) without spinal cord injury and 20 patients (10.8%) with spinal cord injury. Group C (No OPLL and Stenosis group) included 92 patients (88.5%) without spinal cord injury and 12 patients (11.5%) with spinal cord injury. Group B+C (No OPLL) included 258 patients (89%) without spinal cord injury and 32 patients (11%) with spinal cord injury. These findings indicate OPLL group experienced higher incidence of cord injury compared to no OPLL group in the setting of minimal trauma.

In cases of severe (S group) trauma, Group A included 2 patients (33.3%) without spinal cord injury and 4 patients (66.7%) with spinal cord injury. Group B included 11 patients (29.7%) without cord injury and 26 patients (70.3%) with spinal cord injury. Group C included 8 patients (36.4%) without spinal cord injury and 14 patients (63.4%) with spinal cord injury. Group B+C included 19 patients (32.2%) without spinal cord injury and 40 patients (67.8%) with spinal cord injury.

S trauma group was associated with significantly higher incidence of spinal cord injury compared to M trauma group (Cruded OR 12.272, 95% CI 6.724-122.399, Adjusted OR 14.681, 95% CI 7.832-29.518, Table III). These findings indicate there is a higher incidence of cord injury in the setting of sever trauma, independent of OPLL.

With Group B+C (no OPLL group) in M trauma group as the baseline, Group A in M trauma group showed about 5 times as many spinal cord injury (Adjusted OR 4.753, 95% CI 2.351-9.607,

Table II. — Statistical analysis of trauma and spinal cord injury severity across the groups

		OPLL	OPLL (-)		Total	P value
			Spinal stenosis	No stenosis		
ISS**	Mild	2 (3.8%)	31 (13.9%)	32 (25.4%)	65 (16.2%)	< 0.001
	Moderate	44 (84.6%)	155 (69.5%)	72 (57.1%)	271 (67.6%)	
	Severe	5 (9.6%)	35 (15.7%)	22 (17.5%)	62 (15.5%)	
	Very severe	1 (1.9%)	2 (0.9%)	0	3 (1%)	
Neurology	Cord injury	21 (40.4%)	46 (20.6%)	26 (20.6%)	93 (23.2%)	
	None	31 (59.6%)	177 (79.4%)	100 (79.4%)	308 (76.8%)	
	Complete cord injury	3 (5.8%)	5 (2.2%)	2 (1.6%)	10 (2.5%)	
P value		0.003	0.454			

Statistical analysis by Fisher's exact test.
*OPLL : Ossification of Posterior Longitudinal Ligament.
**ISS : Injury severity score.

Table III. — Analysis of factors influencing spinal cord injury

	Crude OR	95% CI	p value	Adjusted OR	95% CI	p value
Age, ≥65 (ref. <65)	1.016	0.588-1.754	0.956			
Sex, Male (ref. female)	0.899	0.514-1.572	0.71			
Spinal stenosis	1.236	0.749-2.040	0.408			
OPLL (+)	2.606	1.414-4.804	0.002	4.024	2.030-7.976	< 0.001
S group*	12.272	6.724-122.399	< 0.001	14.681	7.832-29.518	< 0.001

Statistical analysis by Multiple logistic regression.
*S group : ISS severe, very severe.

$p < 0.001$), Group A in S trauma group had about 16 times (Adjusted OR 16.384, 95% CI 2.862-93.766, $p = 0.002$) and Group B+C 17 in S trauma group had about 17 times (Adjusted OR 16.974, 95% CI 8.777-32.829, $p < 0.001$) the spinal cord injury frequency (Table IV, Fig. 1).

DISCUSSION

Most patients with OPLL present with slowly progressing symptoms of spinal cord compression. However, these symptoms tend be acutely exacerbated when accompanied by trauma. Katoh *et al* have reported that symptoms from spinal cord compression were aggravated after trauma in 16.9% of OPLL patients. This rate was reported to be as high as 28.5% depending on the publication reviewed (*9, 12,17*).

The incidence of OPLL is known to be 2% in the East Asian population (*7*), whereas the incidence of OPLL in patients who underwent surgical treatment for cervical spine trauma was 12.8% in this study, which is significantly higher than those previously reported. This suggests that patients with OPLL are at a higher risk of spinal cord injury requiring surgical treatment among after cervical spine injury.

In this study, OPLL was found to be significantly associated with the occurrence of spinal cord injury, whereas spinal stenosis alone was not. Several studies have reported that both OPLL and spinal stenosis influence trauma-related spinal cord injury. However, this study showed that spinal stenosis

Table IV. — Comparison of spinal cord injuries according to trauma severity and OPLL

		Adjusted OR	95% CI	p value
M group*	OPLL (-)	1		
	OPLL (+)	4.753	2.351-9.607	< 0.001
S group**	OPLL (-)	16.974	8.777-32.829	< 0.001
	OPLL (+)	16.384	2.862-93.766	0.002

Statistical analysis by Multiple logistic regression as reference M group and OPLL(-).
*M group : ISS mild, moderate.
**S group : ISS severe, very severe.

without OPLL has no effect on spinal cord injury. In the setting of spinal stenosis without OPLL, the ability to absorb or disperse a given force is normal because segmental mobility is intact. In contrast, dispersion of external force is decreased in the presence of OPLL because of limited segmental mobility from ossification, thus leading to more severe spinal cord injury. In this study, there were 3 cases (5.8%), 5 cases (2.2%) and 2 cases (1.6%) of complete spinal cord injury in OPLL group (Group A), Stenosis group (Group B) and No OPLL and Stenosis group (Group C), respectively. Even though the differences in incidence were not statistically significant due to the small number of sample, it is probably that the incidence of complete spinal cord injury is higher for patients with OPLL.

Several studies have addressed the risk of severe spinal cord injury in patients with OPLL and spinal stenosis after minor trauma *(12,17,18)*. Katoh *et al (12)* defined minor trauma as a fall on the level, traffic accident, struck by an object, and fall from a height of less than 2 meters without suffering a direct injury to the neck. Yoo *et al (18)* defined minor trauma as falling down (< 2 meters in height), slipping down, motor vehicle accident, struck by objects and sport activities. However, categorizations of injury severity were not objective since those were based on subjective assessment of clinicians. Therefore, evaluation of neurologic injury severity in minor trauma and OPLL seemed to lack reliability. The authors quantified trauma severity using the Injury Severity Score (ISS) in order to provide objective criteria on minor trauma *(1,11)*. The authors evaluated trauma severity in an objective manner using ISS and compared spinal cord injury severity in OPLL patients.

Our results show that with Group B+C (absence of OPLL) in minimal (M) trauma as the baseline, group with OPLL in minimal trauma showed 5 times, Group B+C (absence of OPLL) in severe trauma showed 17 times, and group with OPLL in severe trauma showed 16 times the frequency of spinal cord injury (Table IV). Interestingly, these findings indicate that in the M trauma group, OPLL caused more spinal cord injury with statistical significance compare to no OPLL. However, OPLL did not have statistically significant results in S trauma group, which implies that trauma severity is more closely related to spinal cord injury than presence of OPLL in S trauma group and that OPLL is a more important cause of higher incidence of than no OPLL in minimal trauma. Therefore, clinicians should always be aware of spinal cord injury and perform thorough examinations on spinal cord injury in patients who have sustained severe trauma in the emergency room, regardless of presence of OPLL. In cases of less severe trauma, clinicians should meticulously evaluate radiologic and CT images in order to detect OPLL and anticipate higher possibility of spinal cord injury in the presence of OPLL.

OPLL can be classified into localized type, segmental type, continuous type, and mixed type, using simple radiological images *(17)*. Spinal cord injury had occurred to 6 patients of localized type (28.6%), 7 patients of segmental type (33.3%), 4 patients of continuous type (19%) and 4 patients of mixed type (19%). On the other hand, no spinal cord injury had occurred in 11 patients of localized type (35.5%), 18 patients of segmental type (58.1%), 1 patient of continuous type (3.2%) and 1 patient of mixed type (3.2%). Statistical analysis was not possible due to

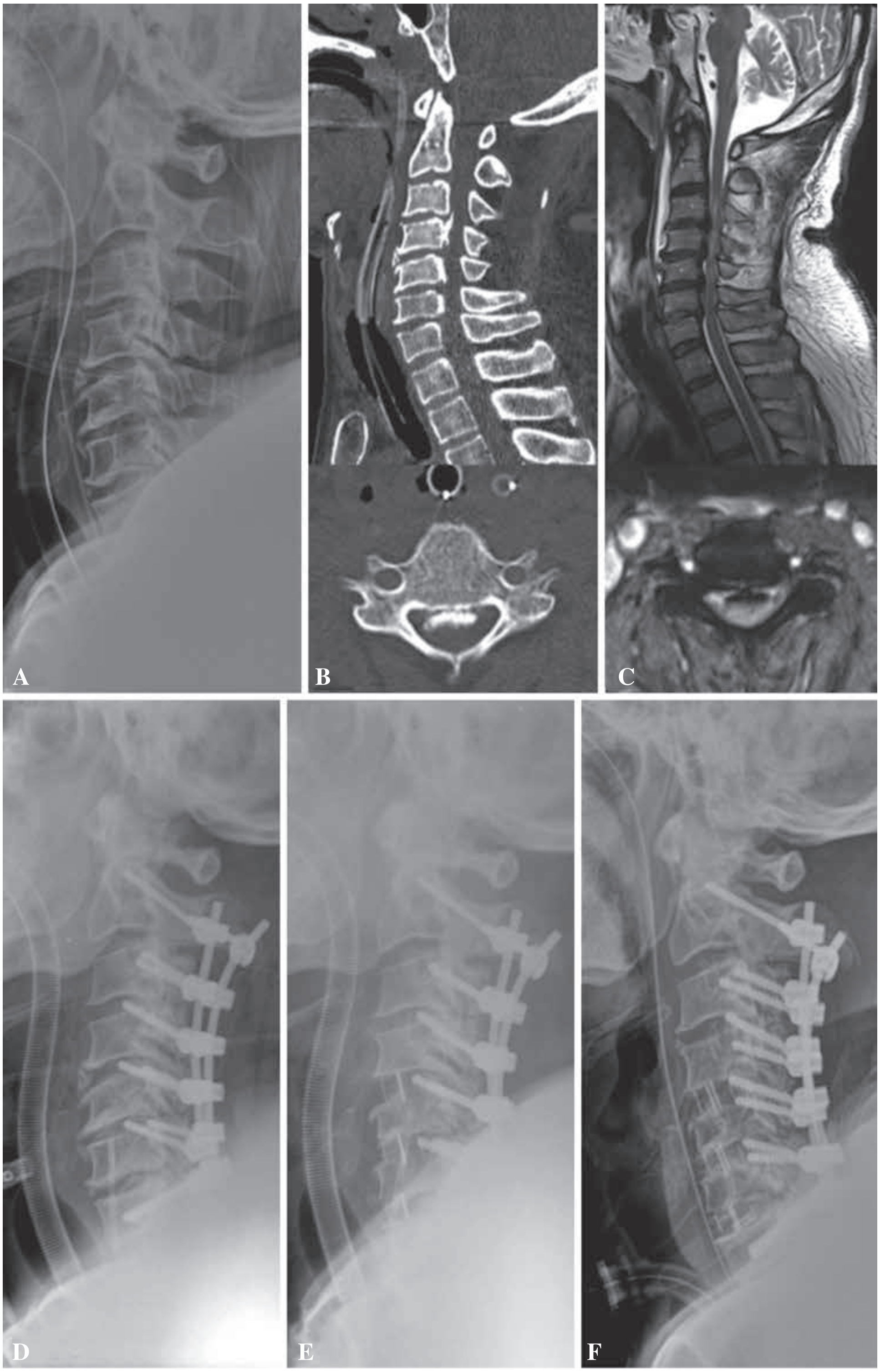

Fig. 1. — Preoperative C-spine lateral X-ray (A), sagittal and axial CT (B), and sagittal and axial T2-weighted MRI (C) of complete cord injury in OPLL patient by minor trauma. Postoperative C-spine lateral X-ray showing posterior fusion and stabilization with rod and screws construct (D) and anterior cervical discectomy and fusion with PEEK cages (E). Follow-up C-spine lateral X-ray showing good alignment and construct status (F).

insufficient number of samples. Classification of cervical OPLL does not seem to be related to spinal cord injury because localized and segmental types were found in both spinal cord injury and without spinal cord injury.

Ages, duration of symptoms, and preoperative neurological deficit are considered to be prognostic factors of cervical OPLL. Patients aggravated by trauma are reported to have much worse post-operative results than those who were not. Even a minor injury can cause irreversible cord damage in the setting of pre-existing spinal compression, which can result in poor post-operative results. Furthermore, secondary injuries from free radical, ischemic change, hemorrhage, or edema cause irreversible damage to the spinal cord (*2,3,10,14*). Some studies have reported that neurologic symptoms improved after surgery in OPLL patients who were aggravated by trauma (*4,15*). In general, treatment of OPLL resulted in poorer outcomes when associated with trauma (*5*). Asymptomatic OPLL patients can experience poor neurological recovery after a minor trauma. Thus, this potential for neurologic sequelae of minor trauma should be considered in patients with OPLL.

The limitation of this study is that the authors only included cases of surgical treatments after trauma and excluded cases of non-operative management. OPLL patients did not require surgical treatment in the absence of neurologic symptoms. Further prospective studies including all patients with cervical spine trauma are expected.

CONCLUSION

There was a high incidence of spinal cord injury in the setting of severe trauma, regardless of OPLL status. However, patients with OPLL more frequently sustained spinal cord injury from minimal trauma. Therefore, clinicians should caution patients with OPLL of the potential for cord injury even with low-energy trauma.

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