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T. Fagerström
R. Hedlund
P. Bancel
R. Robert
B. Dupas

Laminar hook instrumentation in the cervical spine. An experimental study on the relation of hooks to the spinal cord

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T. Fagerström (✉) · R. Hedlund
Department of Orthopedics,
Huddinge University Hospital,
14186 Stockholm, Sweden
e-mail: teddy.fagerstrom@orthoped.hs.sll.se,
Tel.: +46-8-58580000,
Fax: +46-8-58587150

P. Bancel
Department of Orthopedic Surgery,
Clinique Labrouste, Paris, France

R. Robert
Department of Neurotraumatology,
Hôtel Dieu, Nantes France

B. Dupas
Department of Radiology, Hôtel Dieu,
Nantes, France

Abstract Several anterior and posterior methods are today available for stabilization of the cervical spine. Factors such as level and degree of instability, method of decompression, bone quality, length of fixation and safety factors influence the choice of method for a particular patient. The use of laminar hooks in the cervical spine has been restricted by fear of cord compression with the potential of tetraplegia. The aim of the present study was to assess the safety and determine the anatomical relation between hooks inserted in the cervical spinal canal and the dura and spinal cord. Thirteen cadavers from seven women and six men with no evidence of cervical spine disorder were included. The mean age was 81.3 years (range 65–101 years). The cervical spine was instrumented with cervical Compact Cotrel Dubousset hooks and rods. The effect of the hook on the dura was studied by myelography in nine cadavers. The deformation of the dural sac was quantified by measurement of the maximal width of the indentation of the contrast column at each level. A CT myelography scan was obtained in three cadavers. The ratio between the distance of maximal hook intrusion into the spinal canal and the canal diameter in the direction of the hook was calculated. The relation between inserted hooks and the spinal cord and dura was documented in a fresh cadaver studied with CT myelography. A hemilaminectomy was performed at all levels in three cadavers with direct visual inspection and photography of the hook sites before and after excision of the dura. A dural deformation of 2 mm or less, as observed by myelography, was found at four out of 77 (5%) hook sites. The deformation was caused by a supralaminar hook at C3, C6 and C7 and by an infralaminar hook at C6. The mean hook intrusion in the spinal canal, as observed on CT, was 27% (range 8–43) of the canal diameter. On visual inspection, 14 out of 18 hooks were in contact with the dura. After removal of the dura, two out of the 18 hooks in the same cadaver were in contact with the spinal cord. However, no deformation of the cord was observed. To our knowledge this is the first study systematically documenting the relation between hooks and the spinal cord in cadavers. In 95% of the hooks no deformation of the dural sac was observed and there was no evidence of spinal cord deformation. From an anatomical point of view, laminar hook instrumentation can be considered a safe procedure. The study shows, however, that hooks inserted in the cervical spine have a close anatomical relationship with the neuraxis, and at stenotic levels the use of other techniques is therefore recommended.

Keywords Cervical spine · Hook · Fixation · Stenosis

Introduction

Instability of the cervical spine, whether of traumatic, degenerative, rheumatoid or neoplastic origin, may necessitate internal fixation. Several anterior and posterior methods are today available, including anterior plates, posterior wiring, posterior plates with lateral mass screws and posterior rod and hook systems. Based on factors such as the level and degree of instability, the method of decompression, the quality of the bone, the length of the fixation needed and safety factors, a different method may be preferable for a particular patient.

Despite the common use of hooks in the lumbar and thoracic spine, its use in the cervical spine has been restricted, primarily because of fear of cord compression due to the intrusion of hooks in the spinal canal, with the potential of the clinical catastrophe of tetraplegia. In Winter's [6] review of risk factors for neurological deficits in spinal deformity surgery, the risks of neurological complications were in general low. The approximate frequency was estimated at 0.6% in the 1970s and at 0.3% in 1993. Direct trauma to the cord by hook insertion was pointed out as one of the hazards. The safe use of hooks in the thoracic and lumbar spine, however, questions the rational of avoiding laminar hooks in the cervical spine, assuming of course that the size of hooks be adapted to the smaller dimensions of the cervical spine.

The purpose of the present study was to assess the safety of using hooks for fixation of the cervical spine by determining the anatomical relation between laminar hooks and the spinal cord.

Methods

Thirteen cadavers from seven women and six men with no evidence of a cervical spinal disorder were included in the study. The mean age at death was 81.3 years (range 65–101 years). In nine cadavers the cervical spine was instrumented with an identical unilateral Compact Cotrel Dubousset construct (Table 1) in combination with a bilaminar C1-2 claw on the contralateral side. The claw was used since this is a commonly used construct in clinical practice. Unilaminar claws were not used since they are not used in clinical work. The hooks were of standard size and shapes and manufactured in aluminum to minimize distortion of CT imaging. The construct was designed to provide maximum information on the relationship between the hook and the dura and spinal cord, and does not reflect a clinically used construct. In order to minimize canal intrusion, a hook of standard or small size was chosen based on the size of the individual lamina, as in a clinical situation.

The effect of the hooks on the dura was studied by myelography. The myelography was performed in a supine position on nine cadavers and in both prone and supine position on one cadaver (Table 2). The cerebral spinal fluid (CSF) was replaced by a contrast medium. Deformation of the dural sac was quantified by measuring the maximal width in millimetres of the indentation of the contrast column at each level. In one cadaver (no. 13) we studied the influence of a supralaminar versus an infralaminar hook position by observations in both locations, i.e. the cervical spine was first instrumented with all hooks in the supralaminar position, after which they were switched to an infralaminar position.

For additional analysis of the transverse plane, a CT myelography scan was obtained in three of the cadavers (Table 3). The mean sagittal diameter of the subaxial cervical spinal canal was 14.2 mm (range 12–18 mm) and that of the upper cervical spine (C1–C2) was 15.1 mm. The ratio between the distance of maximal hook intrusion into the spinal canal and its diameter in the direction of the hook was calculated. In addition, in one cadaver (no. 12), all deformations of the cord and/or dura were documented. Due to technical difficulties (dye leakage), this could not be quantified in the other two cadavers. To determine whether the hooks not only deformed the dural sac, but also the spinal cord, a hemilaminectomy was performed at all levels in three cadavers (no. 9, 12, 13) with direct visual inspection and photography of the hook sites before

Table 1 Position of the cervical CD hooks in nine cadavers investigated with myelography

Level	Right	Left
C1		Supralaminar
C2	Supralaminar	Infralaminar
C3	Supralaminar	
C4	Infralaminar	
C5	Supralaminar	
C6	Supra-/Infralaminar	
C7	Supralaminar	

Table 2 Impression (mm) of the dura in myelography of nine cadavers instrumented with supra- and infralaminar hooks in supine position. Cadaver 3 and 4 investigated in both supine and prone position (*x* image not interpretable, - no hook inserted)

Cadaver no.	C1 Supra	C2 Infra	C2 Supra	C3 Supra	C4 Infra	C5 Supra	C6 Supra	C6 Infra	C7 Supra
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3 (supine)	0	0	0	0	0	0	0	1	2
3 (pron)	0	0	0	0	0	0	0	0	1
5 (supine)	0	0	0	0	0	0	0	0	0
5 (prone)	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	2	0	0
8	x	-	0	0	0	0	0	0	0
10	0	0	0	2	0	0	0	0	0
11	x	x	0	0	0	0	0	0	0

Table 3 Quantification of canal encroachment by laminar hooks in three cadavers by CT myelography (*A* sagittal diameter of the spinal canal, *B* hook occupation of spinal canal in the direction of hook, *C* distance between hook and spinal cord, *X* no data available, *sin* right, *dx* left)

Level	Cadaver 1 A mm	Cadaver 1 sin B %	Cadaver 1 dx B %	Cadaver 4		Cadaver 12		
				A mm	B %	A mm	B %	C mm
C1 supra	X	X	29	18	29	X	25	2
C2 supra	14	25	X	14	29	16	22	4
C2 infra	14	X	29	14	8	16	17	4
C3 supra	12	29	X	12	29	16	20	4
C4 infra	14	43	38	14	29	16	33	2
C5 supra	12	29	29	14	33	16	29	2
C6 supra	16	22	22	14	29	12	33	1
C6 infra	16	22	29	14	25	12	29	2
C7 supra	14	25	25	18	20	14	25	1
Mean	14	28	29	15	26	15	26	2

Fig. 1 Supralaminar hooks placed in an experimental construct. View of the dura after contralateral hemilaminectomy

Fig. 2 Supralaminar hooks placed in an experimental construct. View of the spinal cord after contralateral hemilaminectomy and excision of the dura

(Fig. 1) and after (Fig. 2) excision of the dura. The possible decrease in intradural pressure could not be quantified and could therefore lead to an underestimation of the effect of the hook on the dura, but not on the spinal cord.

Results

In the myelographic study a deformation of the dural sac was observed in three cadavers at four out of 77 hook sites (5%) (Table 2). The age at death of the cadavers with dural impression was 78, 101 and 88 years (mean 89). The maximal impression of the dye column was 2 mm. Three out of 52 (6%) supralaminar hooks and one out of 25 (4%) infralaminar hooks caused a dural impression (nonsignificant). When measuring in both prone and supine position, a dural impression was found in one out of the two cadavers. The dura was deformed at two hook sites in the supine position and at one site in the prone position. In the CT study, the mean distance between the hook and anterior aspect of the spinal canal, in the direction of the hook, was 11.7 mm (range 8–24 mm) (Table 3), corresponding to a hook intrusion into the spinal canal by 27% (range 8%–43%). Contact between the hook and the dura in the cadaver with a CT-myelographic study was observed for all hooks inserted at all levels except at C1. There were no signs of cord compression. A hemilaminectomy and visual inspection were preformed for three cadavers (no. 9, 12, 13). No contact with the dura was found in 22% of the hooks whereas 78% were in contact with the dura. After removal of the dural sac, 91% of the hooks showed no contact with the spinal cord and 2% (2 supralaminar hooks at C5 and C6, respectively) of the hooks were in contact with the cord without evidence of deformation (Table 4).

Discussion

To our knowledge this is the first study systematically documenting the anatomical relation between laminar hooks and the spinal canal and spinal cord in cadavers. We

Table 4 Visual evaluation of contact between supra- and infralaminar CD hooks and the dura and the spinal cord in three cadavers (- no hook inserted, *C* contact, *NC* no contact)

Level	Cadaver 9		Cadaver 12		Cadaver 13	
	Contact dura	Contact cord	Contact dura	Contact cord	Contact dura	Contact cord
C1 supra	-	-	-	-	C	NC
C1 infra	-	-	-	-	-	NC
C2 supra	C	NC	C	NC	C	NC
C2 infra	-	-	-	-	-	NC
C3 supra	NC	NC	C	NC	NC	NC
C3 infra	-	-	-	-	-	NC
C4 supra	-	-	C	NC	C	NC
C4 infra	NC	NC	-	-	-	NC
C5 supra	NC	NC	C	-	C	C
C5 infra	-	-	C	-	-	NC
C6 supra	C	NC	-	-	C	C
C6 infra	C	NC	-	-	-	NC
C7 supra	-	-	-	-	C	NC
C7 infra	-	-	-	-	-	NC

found that the great majority of hooks did not cause a deformation of the dura and there was no deformation of the spinal cord. These results suggest that the neurological risk of using laminar hooks in the cervical spine is limited. The observed close relation between the hooks and the neuraxis should, however, be noted. Our findings are in agreement with the extensive use of the hooks in the thoracic spine since the introduction of Harrington instrumentation, with a low frequency of neurological complication [10], and also with our clinical experience of laminar hooks inserted in the cervical spine [3].

In the present study we studied the cervical spine of elderly individuals with the dimension of the spinal canal affected by degenerative changes, i.e. most likely more narrow canals than in younger adults. The observed mean subaxial canal diameter was 14.2 mm, which is within the normal limits in most reported series of cervical spinal canal measurement [4, 6, 8, 9]. The cadavers were randomly selected and it cannot be excluded that some of them had a relative cervical spinal canal stenosis. Since the purpose of the study was to document any potential risk, we found it appropriate to study cadavers of elderly patients with potentially stenotic spines. There were, however, no cadavers with an obvious stenotic spine; the lowest sagittal diameter observed was 12 mm, which is higher than what commonly is referred to as indicative of stenosis.

Except for the larger range of motion of the cervical spine, there is little rationale in claiming that hooks with dimensions adjusted for the smaller dimensions of the cervical spine should be more of a threat to the spinal cord than thoracic hooks. No difference in canal intrusion could be demonstrated between the prone and the supine position, suggesting that hooks do not change position but are firmly seated on the laminae. The consequence of cervical cord injury is, however, enormous and the use of hooks in the cervical spine presupposes a well-trained surgeon with a thorough understanding of cervical spine anatomy and the inherent risks and limitations of the technique. Laminar hooks are often in close contact with the dura and sometimes also with the cord, clearly showing that close attention to detail is mandatory in hook instrumentation of the cervical spine. This is particularly true for the supralaminar hook, which seems to be in closer relation to the dura than the infralaminar hook. A hook groove larger than the thickness of the lamina obviously produces a greater canal occupation and should be avoided. In cervical spinal stenosis, the close relation between the blade of the hook and the neurological structures encourages a cautious use at stenotic levels and suggests that a thinner blade would be advantageous.

In cervical spine surgery a majority of patients are elderly with concomitant osteoporosis, tumors or rheumatoid disease, all associated with poor bone quality. In a human cadaver study, Bueff et al. [2] showed that the pediatric CD system with laminar hooks and a crosslink provided a larger increase in stiffness of the cervicothoracic junction (C7–T1) than did the posterior lateral mass plates and anterior plate.

The lateral mass screw is associated with a risk of nerve root and vertebral artery damage [1, 7]. Heller et al. [6] reported immediate radicular symptoms in seven patients (9%), cerebellar infarction in one and anterior horn infarction in one out of 78 patients operated on with posterior cervical plating with attempted bicortical lateral mass screw purchase.

In non-osteoporotic bone, anterior plate fixation is associated with few problems. But low bone density is considered a relative contraindication [11]. Taking into consideration the potential benefit of hook fixation in the osteoporotic spine and the few known problems when used in the thoracic and lumbar spine, the hook-based system adds to the treatment options in cervical spine surgery. The present findings add to our understanding of the risk-benefit ratio in using cervical hooks.

Conclusion

In the present experimental study we found that 95% of the cervical laminar hooks did not affect the dura and there was no evidence of spinal cord compression. Since contact with the cord was observed on visual inspection, however, laminar hooks should be avoided at stenotic levels. The study also shows that there is a need for downsized implants to minimize canal intrusion. It can be concluded that laminar hooks can be used in the cervical spine with similar risks and benefits as in the thoracic spine.

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