C5 palsy after cervical laminoplasty

A MULTICENTRE STUDY

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We have reviewed 1858 patients who had undergone a cervical laminoplasty and identified 43 (2.3%) who had developed a C5 palsy with a MMT (MRC) grade of 0 to 2 in the deltoid, with or without involvement of the biceps, but with no loss of muscular strength in any other muscles. The clinical features and radiological findings of patients with (group P; 43 patients) and without (group C; 100 patients) C5 palsy were compared. CT scanning of group P revealed a significant narrowing of the intervertebral foramen of C5 ($p < 0.005$) and a larger superior articular process ($p < 0.05$). On MRI, the posterior shift of the spinal cord at C4-5 was significantly greater in group P, than in group C ($p < 0.01$).

This study is the first to correlate impairment of the C5 nerve root with a C5 palsy. It may be that early foraminotomy in susceptible individuals and the avoidance of tethering of the cord by excessive laminoplasty may prevent a post-operative palsy of the C5 nerve root.

Cervical compression myelopathy is a common cause of serious morbidity in the middle-aged and elderly, and classically presents with progressive spastic quadriparesis, sensory loss at or below the neck, and urinary incontinence.[1,2] The accepted treatment for the underlying stenosis of the cervical canal is some form of surgical decompression or stabilisation.[3-7] The number of patients needing surgery has increased proportionately with the increasing age of the population. Cervical laminoplasty has been widely performed and has given good results, as it is easy, safe and effective, and there is now no need for external bracing.[8-12] However, post-operatively, a C5 palsy remains a serious complication.[13,14] Although its prevalence is low, affected patients suffer from muscle weakness, brachialgia and numbness, and are dissatisfied with their surgery. Various aspects of the surgical procedure, pathology of the spinal cord and impairment of the nerve root have been implicated as causes of a C5 palsy,[15-19] but owing to its low prevalence most studies have included only a few patients. This has prevented any clarification of the pathology and the resultant development of preventive methods.[20,21] In addition, many studies have also included cases of paralysis of other nerves (C6, C7 and C8) after laminoplasty,[15,17,19] which has complicated matters. The objectives of this study were to review the clinical and radiological findings in patients with a C5 palsy (manual muscle test (MMT) score < 3) after cervical laminoplasty and to look for any features on the pre-operative imaging that might help to predict its occurrence. The MMT score is very similar to the MRC grade,[22] and uses the same 0 to 5 grading system.

Patients and Methods

Between 1991 and 2005, 1858 patients underwent cervical laminoplasty for a chronic compression myelopathy at hospitals in the Nagoya Spine Group. There were 1096 men and 762 women, with a mean age of 62.5 years (36 to 93) at the time of surgery. There were 1570 patients with a cervical spondylotic myelopathy and 288 with ossification of the posterior longitudinal ligament. All patients were followed for at least two years after surgery.

A C5 palsy was defined as a paresis of deltoid (MMT score 1 or 2), with or without involvement of the biceps, but no loss of strength in other muscles. We excluded 159 patients with injuries, tumours, rheumatoid arthritis, a destructive spondyloarthritis caused by haemodialysis, previous cervical surgery, an MMT score of 3 to 5 or a C6 to C8 palsy.

Cervical laminoplasty was performed with the patient lying prone on a Hall frame under general anaesthesia. Most of the operations were performed without neurological monitoring. After operation, patients were kept in bed for two or three days. After removal of their drains they were allowed to mobilise in a soft cervical collar, which they wore for one to four weeks depending on the severity of their neck pain.

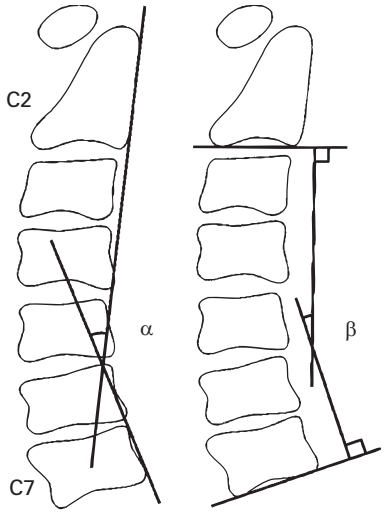

Fig. 1a Fig. 1b

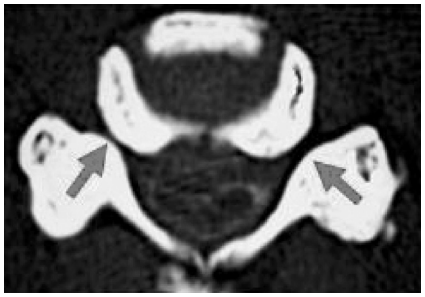

Fig. 1d

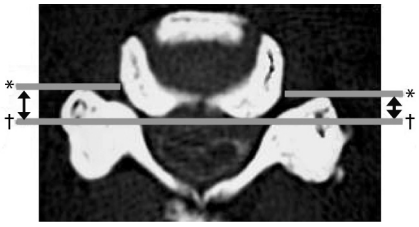

Fig. 1e

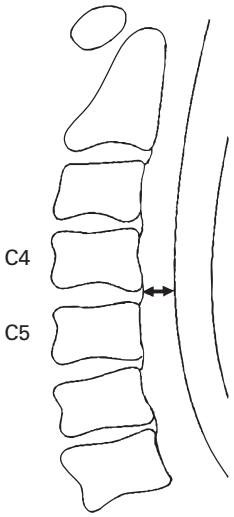

Fig. 1c

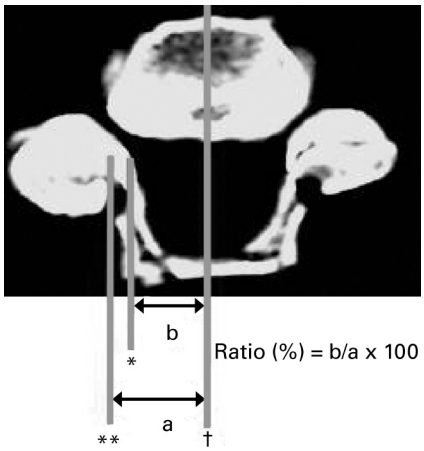

Fig. 1f

Diagrams of radiological assessment. a and b) cervical curvature (α) and Cobb angle (β) at C2 to C7 on a plain radiograph. c) posterior shift of the spinal cord at C4-5 on mid-sagittal MRI (double arrow). Radiological measurements by CT recorded bilaterally. d) The width of the C5 foramen was measured at the narrowest point (arrow). e) the anterior protrusion of the C5 superior articular process (SAP) (double arrow). † indicates the posterior line of the vertebral column. * indicates the line of the most prominent site of the C5 SAP parallel to the posterior line of the vertebral column. f) The ratio of the width of the bony gutter and the facet joint, reflecting the position of the bony gutter. † indicates the midline of the vertebral column, * indicates the medial point of the bony gutter, ** indicates the medial point of the facet joint. These lines are vertical to the posterior line of the vertebral column. The distances between † and ** (a), and between † and * (b) were measured. All these measurements were adjusted for the actual length.

The records of doctors, nurses and rehabilitation staff were reviewed by SI and were found to be complete. Any C5 palsy was diagnosed during the course of routine post-operative examination by a spine specialist with at least 15 years' experience (one of the authors).

The clinical features of each patient were recorded and any difference between those of patients with (43 patients) and without (1815 patients) a C5 palsy were noted. These features included age, gender, duration of symptoms, disease, operating time, estimated blood loss, type of surgical procedure, laterality and onset of paralysis, pre- and post-operative symptoms, treatment of C5 palsy, period of recovery, level of recovery of motor paralysis, pain and sensory disturbance, and recovery of neurological function calculated from the pre- and post-operative Japanese Orthopaedic Association scores.[23] This score is based on the rating of motor function (fingers, 0 to 4 points; shoulder and elbows, -2 to 0 points; and lower extremity, 0 to 4 points), sensory function (upper extremity, 0 to 2 points; lower extremity, 0 to 2 points; and trunk, 0 to 2 points) and urinary bladder function (0 to 3 points). A normal Japanese Orthopaedic Association score is 17 points. The recovery

Table I. Characteristics of patients who developed a C5 palsy among 1858 patients who underwent laminoplasty

	C5 palsy	No C5 palsy	Control group	p-value*
Number of patients (%)	43 (*2.3*)	1815	100	
Mean age in yrs (range)	63.3 (46 to 81)	62.5 (40 to 85)	61.3 (41 to 84)	NS
Gender				
Male	32	1064	75	
Female	11	751	25	NS
Mean duration of symptoms (mths)	27.8 (2 to 144)	29.5 (1 to 223)	29.1 (1 to 220)	NS
Disease				
Cervical spondylotic myelopathy	33	1537	75	
Ossification of the posterior longitudinal ligament	10	278	25	NS
Mean operating time in mins (range)	124 (62 to 216)	121 (45 to 190)	122 (81 to 180)	NS
Mean estimated blood loss in ml (range)	99.5 (10 to 450)	99.0 (5 to 425)	99.1 (10 to 400)	NS
Mean Japanese Orthopaedic Association scores				
(Pre-op)	10.5 (5 to 15)	10.1 (2 to 15)	10.2 (4 to 15)	NS
(2 years post-op)	13.1 (8 to 16.5)	13.5 (3 to 17)	13.7 (4 to 17)	NS
(% improvement)	41.4 (0 to 93)	47.5 (0 to 100)	48.7 (0 to 100)	NS

* the p-value for comparison of the groups with and without C5 palsy; NS, not significant

rate was calculated using Hirabayashi's method[9] based on the formula:

recovery rate (%) = [(post-operative score - pre-operative score) × 100]/17 - pre-operative score).

We also reviewed the radiological findings from plain radiographs, MRI and CT scans. The cervical lordotic angle (cervical curvature, α[24]; Cobb angle, β[25]) (Figs 1a, 1b), intervertebral angle (C4-5; positive value indicates lordotic angle), local kyphosis angle, and cervical alignment were assessed on a standard lateral radiograph in neutral, in instability (an intervertebral range of movement $\geq 5°$) and in the presence of listhesis ($\geq$ 2 mm) on flexion and extension views.

The cervical spine was classified as lordotic ($> 5°$), straight ($-5° \leq \alpha \leq 5°$), sigmoid, or kyphotic ($\alpha < -5°$).

MRI was used to assess the number of levels of compression, the most compressed level of the spinal cord, and the presence of a high-intensity area in the spinal cord on the T2-weighted images pre-operatively. The level and extent of the high-intensity area (classified as focal and linear) were also checked post-operatively, as was the post-operative posterior shift of the spinal cord (C4-5) in the mid-sagittal plane (Fig. 1c).[26]

CT was used to measure the width of the intervertebral foramen at C5 (Fig. 1d), the anterior protrusion of the superior articular process,[27] of C5 (Fig.1e), the presence of hinge dislodgement, and the position of the bony gutter (Fig. 1f). The CT images were acquired in the horizontal plane of the intervertebral disc. The width of the C5 intervertebral foramen was measured at its narrowest point, and the anterior protrusion of the superior articular process of C5 was measured at its most prominent. The gutter position was expressed as the ratio of the distance between the midline of the vertebral column at C5 and the medial point of the gutter relative to the distance between the midline of the vertebral column at C5 and the most medial part of the facet joint (Fig. 1f).

In order to compare the radiological findings of patients with a C5 palsy (group P) and those without (control group C), 100 patients were randomly selected from the 1815 patients without C5 palsy. A total of 43 patients with a C5 palsy were identified from eight different hospitals. Their controls were selected according to the ratio of patients with C5 palsy in each of the hospital populations. For instance, if an institute had three palsy cases (3 of 43: 7%), seven controls (7 of 100: 7%) were selected from the same hospital, and matched by year of operation, disease, age and gender (Table I). The control cases were selected by a secretary who was unaware of the imaging findings for the patients. If there was no control case with a complete match to a palsy case, the year of operation and disease were used preferentially. This resulted in a slightly higher percentage of women in the control group than in the C5 palsy group, but this difference was not significant.

The radiographic measurements (mm) of individual images were adjusted for the actual length. Each image was then independently evaluated twice by the same two spine specialists (SI, RT), who were unaware of the clinical and neurological status of the patient. The correlations between the first and second measurements of either examiner ranged from 0.904 to 0.958 ($p < 0.0001$) for all radio-

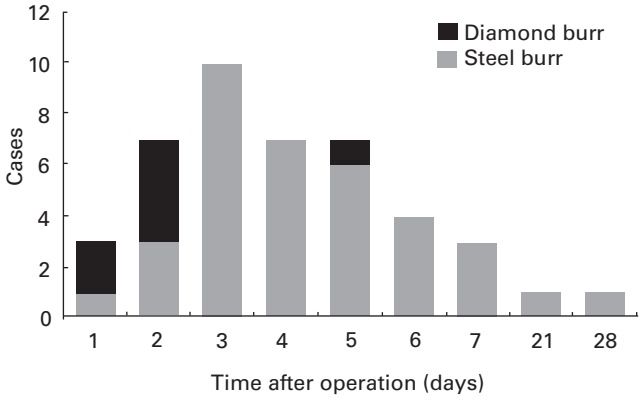

Fig. 2

Graph showing the onset of C5 palsy which occurred at a mean of 4.7 (1 to 28) days after surgery. The patients were allowed to sit and stand on post-operative days 2 or 3. The majority of patients (38) developed C5 palsy after sitting and standing, and 26 developed C5 palsy on the first or second day of standing.

logical measurements. The correlations between the examiner's measurements ranged from 0.913 to 0.943 ($p < 0.0001$). Means were calculated, and from these the standard error of the mean (SEM) was obtained.

An unpaired *t*-test, Mann-Whitney U test, Fisher's exact probability test or Pearson's correlation coefficient were used for statistical analysis, with $p < 0.05$ taken to indicate statistical significance.

Results

The characteristics of patients with and without a C5 palsy are shown in Table I. Of 1858 patients who underwent a cervical laminoplasty, 43 (2.3%, 95% confidence interval (CI) 0.017 to 0.031) developed a C5 palsy with an MMT score < 3 (group P). There were 32 men and 11 women with a mean age at the time of surgery of 63.3 years (46 to 81). The mean duration of symptoms was 27.8 months (2 to 144). In all, 33 and ten patients had cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament, respectively. In group P, 28 patients underwent unilateral open-door laminoplasty and 15 a French-window laminoplasty. In group C, unilateral open-door laminoplasty was carried out in 63 patients, and French-window laminoplasty in 37. In group P, the mean operating time was 124 minutes (62 to 216) and the mean estimated blood loss was 99.5 ml (10 to 450). In group C the mean operating time was 122 minutes (81 to 180) and the mean estimated blood loss was 99.1 ml (10 to 400). The patient characteristics, disease process and the type of surgical procedure had no significant effect on the prevalence of C5 palsy.

No patient with a C5 palsy needed a further operation. All were treated conservatively with rest, rehabilitation of muscle strength and range of movement exercises in bed, intravenous corticosteroids for two or three days, and further physiotherapy once their pain subsided. The mean Japanese Orthopaedic Association score for the 43 patients with a C5 palsy improved from 10.5 (5.0 to 15.0) pre-operatively to 13.1 (8.0 to 16.5) at two years' follow-up, an improvement of 41%. There was no significant difference in the recovery rate between the two groups (Table I).

Surgical procedure. In group P, of the 28 patients who had a unilateral open-door laminoplasty, paralysis occurred on the open side in 13, the hinge side in 14, and on both sides in one. Of the 15 patients who had a French-window laminoplasty, 14 had paralysis on one side and one on both sides. There was no significant correlation between the surgical procedure and the side that was paralysed. A high-speed drill was used in each case, with a steel burr for 37 patients, a diamond burr for four, and both types for two patients. Patients who were operated on with a diamond burr developed a more severe motor paralysis in their deltoid muscle ($p = 0.048$), but there was no correlation between the type of drill used and the period or extent of recovery from paralysis.

Onset of C5 palsy. Paralysis was noted after a mean of 4.7 (1 to 28) days post-operatively (Fig. 2). There were five patients who developed a C5 paralysis in the first two post-operative days before they had been mobilised: three of the five had been operated on using a diamond burr. The other 38 patients (88%) became paralysed after mobilising: 18 (42%) on the first day of standing and eight (19%) on the second day.

Motor paralysis. The mean MMT score at the onset of paralysis was 1.6 (0 to 2) for deltoid and 2.8 (0 to 5) for biceps brachii. Conservative treatment resulted in complete recovery from motor paralysis in 29 patients (67%) and a residual motor paralysis with mean MMT scores of 3.2 (1 to 4) (deltoid) and 3.6 (2 to 5) (biceps) in 14. The mean time to complete recovery from paralysis was 4.1 months (3 days to 17 months), except for one patient who showed no recovery after five years. The mean MMT scores in patients who exhibited residual paralysis were 1.2 (0 to 2) (deltoid) and 2.0 (0 to 4) (biceps) at onset, compared to 1.8 (1 to 2) (deltoid) and 3.1 (1 to 5) (biceps) in patients who recovered completely, indicating that those with severe motor defects initially fail to recover completely ($p = 0.0090$).

Pre-operatively, of the group P patients, 36 (84%) had no muscle weakness in the upper limb, including the C5 area but seven (16%) had a motor deficit with muscle weakness and an MMT score of 3 or 4. This was on the side of the subsequent paralysis in five patients, on the opposite side in one, and on both in one patient. These seven cases took considerably longer to recover their pre-operative level ($p < 0.05$), but there was no correlation between pre-operative muscle weakness and degree of recovery from paralysis.

Brachialgia and numbness. Pain in the distribution of the C5 nerve root accompanied the C5 palsy in 34 patients (79%). This recovered completely with conservative treatment in 28 patients (82%), but three were left with mild pain and three had continuous pain at the final follow-up (6 of 34: 18%). Pre-operatively, 38 patients (88%) had some numb-

Table II. Radiological assessment of the C5 palsy and control groups

	C5 palsy	Control	p-value
Plain radiograph			
Lordosis (mean; range)			
α angle (pre-operative) (°)	15.2 (-22 to 41)	16.6 (-8 to 45)	0.59
α angle (post-operative) (°)	14.4 (-27 to 42)	15.3 (-20 to 46)	0.70
β angle (pre-operative) (°)	10.2 (-25 to 40)	10.4 (-21 to 39)	0.98
β angle (post-operative) (°)	9.8 (-33 to 47)	8.3 (-25 to 38)	0.55
MRI			
Number of compression levels	2.9 (1 to 6)	2.7 (1 to 5)	0.60
Most compressive level (C3-4) (cases) (%)	15 (*35*)	27 (*27*)	0.54
HIA* (cases) (%)	33 of 43 (*77*)	78 of 100 (*78*)	0.49
HIA level (C3-4) (cases) (%)	8 (*24*)	21 (*27*)	0.50
Focal HIA (cases) (%)	29 (*88*)	65 (*83*)	0.77
Linear HIA (cases) (%)	4 (*12*)	13 (*17*)	0.20
Posterior shift of the spinal cord (C4-5) (mm)	3.9 (0 to 7.5)	3.0 (0 to 7.5)	0.0091
CT			
Width of the C5 intervertebral foramen (mm)			0.0043‡
Palsy side (C5 palsy)/right side (control)	1.6 (0.5 to 5.0)	4.3 (1.7 to 7.3)	< 0.0001§
Normal side (C5 palsy)/left side (control)	2.1 (0.8 to 7.0)	4.3 (1.0 to 7.2)	< 0.0001¶
Anterior protrusion of the C5 superior articular process (mm)			0.029‡
Palsy side (C5 palsy)/right side (control)	5.1 (0.25 to 9.2)	3.5 (0 to 10.0)	< 0.0001§
Normal side (C5 palsy)/left side (control)	4.3 (1.25 to 8.3)	3.5 (0 to 8.3)	0.048¶
Position of the bony gutter (%)			0.94‡
Palsy side (C5 palsy)/right side (control)	85.6 (50 to 133)	81.6 (50 to 100)	0.19§
Normal side (C5 palsy)/left side (control)	85.6 (61.5 to 175)	82.4 (55.6 to 100)	0.22¶

* HIA, high intensity areas

† values are given as means

‡ palsy side *vs* normal side

§ palsy side *vs* control

¶ normal side *vs* control

ness in the C5 distribution on the affected side, and this remained unchanged after laminoplasty in all except ten patients, in whom the numbness improved slightly. There was no significant difference in the time to motor recovery between these ten patients and the others, but those in whom numbess improved had significantly greater improvement of motor power in the deltoid and biceps ($p < 0.05$).

Radiological. The degree of cervical lordosis remained the same in both groups (Table II). In group P, the mean pre-operative intervertebral angle at C4-5 was 3.9° (-8° to 14°) and the mean post-operative intervertebral angle was 2.9° (-6° to 12°). In group P a post-operative local kyphosis was present in six patients, a posterior listhesis in five, and intervertebral instability in one: these were no worse at final follow-up at a minimum of two years. Post-operatively one patient developed a local kyphosis at C5-6, and two a retrolisthesis of C4. There was no correlation of these with the extent or duration of recovery from the C5 palsy.

Changes in cervical alignment are shown in Figure 3. There were no significant findings.

In group P, MRI showed that the mean number of levels at which the spinal cord was compressed was 2.9 (1 to 6; Table II), most frequently at C4-5 (Fig. 4). Pre-operative T2-weighted MRI demonstrated a high intensity area in 33 patients (77%) at 36 levels. These were at C3-4 in eight patients, C4-5 in 15, C5-6 in six, C6-7 in one and at C3-4+C4-5 in two, and at C4-5+C5-6 in one (Fig. 4). A high intensity area at a level corresponding to the C5 segment (C3-4) was evident in only ten patients (23%). Focal high intensity areas were present in 29 patients (58%) and linear high intensity areas in four (12%) patients in group P. In group C, 78 patients (78%) had a high intensity area. Focal high intensity areas were present in 65 (83%) and linear high intensity areas in 13 (17%). There were no significant differences between the two groups in the number and location of the compressed levels, or the prevalence and type of high intensity area. However, the mean post-operative posterior shift of the spinal cord at C4-5 was 3.9 mm (0 to 7.5) in group P and 3.0 mm (0 to 7.5) in group C ($p = 0.0091$) (Table II). There was no significant relationship between the shift of the spinal cord and the level of recovery from paralysis in group P.

On CT measurement, a difference in width between the intervertebral foramina was confirmed in 20 patients (47%); in 16 (80%) the side of the narrowing corresponded with the side that was paralysed. In group P, the mean width

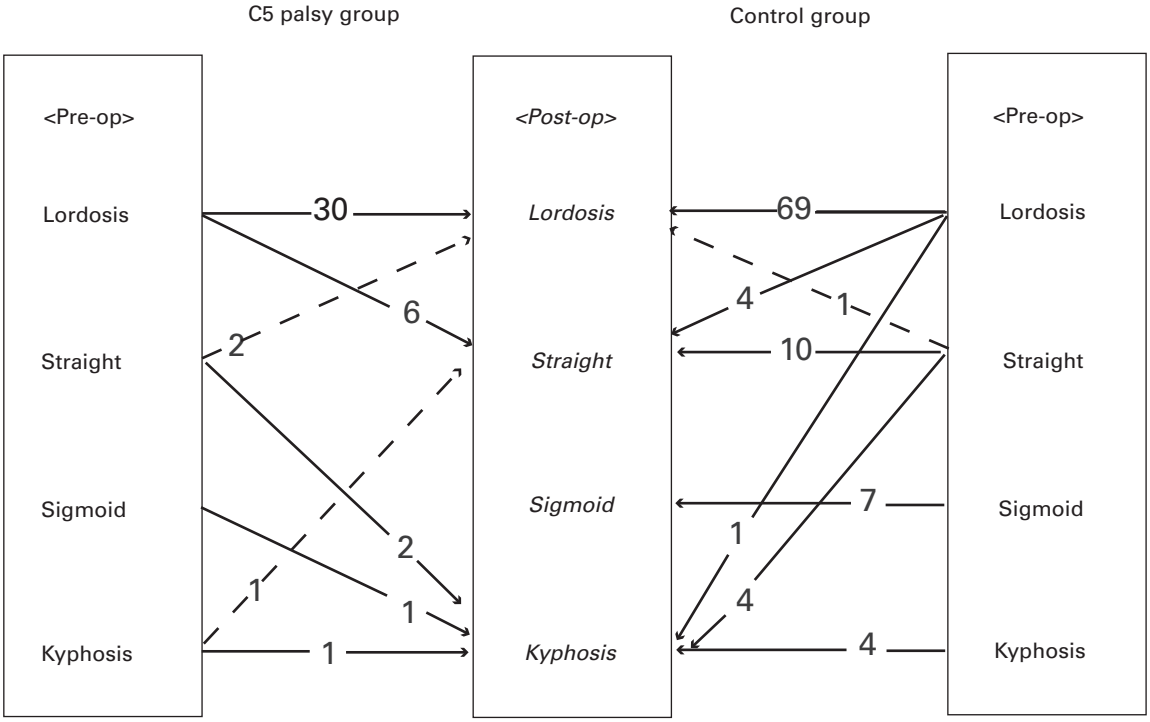

Fig. 3

Diagram showing pre- to post-operative changes in cervical alignment in the two groups. Cervical alignment was maintained in most cases in both groups. The findings were variable and the changes in cervical alignment showed no trend for either group or difference between the groups.

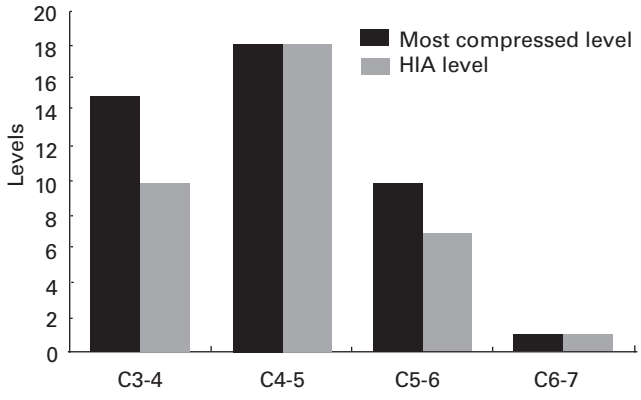

Fig. 4

Graph showing the most compressed level and high intensity area (HIA) level on MRI in cases of C5 palsy. An HIA at a level corresponding to the C5 segment (C3-4) was evident in only ten patients (23%).

of the intervertebral foramen was significantly less on the paralysed than on the normal side (1.6 mm *vs* 2.1 mm, p = 0.0043) (Table II). The mean anterior protrusion of the superior articular process of C5 was significantly greater on the paralysed than the normal side (5.1 mm *vs* 4.3 mm, p = 0.029). In group C, the mean width of the C5 intervertebral foramen (4.3 mm) was significantly greater and the degree of anterior protrusion of the superior articular process of C5 (3.5 mm) significantly less than on either the paralysed or the normal side in group P (p < 0.0001) (Table II). In group P the ratio reflecting the position of the bony gutter was 85.4% on the paralysed side and 85.6% on the normal side, whereas in group C these ratios were 81.6% on the right and 82.4% on the left side, with no significant effect on the development of C5 palsy (Table II). There were no cases of dislodgement of the hinge.

Discussion

Laminoplasty is an essentially safe procedure which allows the surgeon to decompress the cervical spine over a wide area. Consequently, it has been used for the treatment of compressive cervical myelopathy with favourable results.[28-31] However, one serious complication is a C5 palsy. In our series of 1858 laminoplasties, we identified 43 such cases. This is a relatively low incidence, but it should be appreciated that we only included severe patients with an MMT score of 2 or less. Other studies have included cases of higher grade, and some also include palsies of C6, C7 and C8 (Table III).

A number of causes have been suggested, including pathology of the spinal cord, nerve root impairment and the surgery itself.[15-19] In our study, the early development of a C5 palsy when the patient was still in bed suggested that it was not associated with loading of the spine by standing

Table III. Reported cases of upper limb palsy after laminoplasty

Authors	Level of palsy	Muscle weakness	Cases	Incidence (%)	Procedure*
Yonenobu et al[22]	C5	MMT = 3 to 5	4/95	*4.2*	Unilateral
Tsuzuki et al[34]	C5 - 8	MMT ≤ 5†	20/188	*10.6*	6 surgical procedures
Satomi et al[30]	C5, C6	MMT ≤ 4	6/51	*11.8*	Unilateral
Uematsu et al[19]	C5 - 7	MMT ≤ 5‡	20/365	*5.5*	Unilateral, French-window
Edwards et al[20]	C5	MMT = 0	1/18	*5.6*	French-door
Wada et al[40]	C5	NA¶	4/24	*16.7*	Unilateral
Chiba et al[15]	C5 - 8	NA	15/208	*7.7*	Unilateral
Hasegawa et al[17]	C5 - 8	NA	21/345	*6.1*	Unilateral, French-window
Current study	C5	MMT < 3	43/1858	*2.3*	Unilateral, French-window

* unilateral, unilateral hinge laminoplasty; French-window, French-door laminoplasty

† including sensory dominant paralysis

‡ including post-operative radiculopathy only

¶ NA, not available

or sitting. It was, however, frequently observed after surgery using a diamond burr. It is our opinion that the nerve root was probably damaged at the time of operation by heat generated by the high-speed drill, which would make it an iatrogenic injury. This risk has been further recently highlighted in an experimental porcine lumbar spine model by Hosono et al.[32]

Chiba et al[15] have suggested that local reperfusion of the spinal cord may cause cellular damage. This is based on the appearance on an MRI of high intensity areas at a significantly higher rate in patients with post-operative paresis of the upper limb than in those without. Furthermore, in their study, the high intensity areas corresponded to the level of the paralysed segment. Previous reports have also suggested that linear high intensity areas are seen more often on MRI at the paralysed level.[26,33] However, we found no difference in the occurrence of these areas between patients with and without a C5 palsy. Also, as most patients (95%; 41 of 43 patients) exhibited unilateral paralysis, we found it difficult to conclude that the cells of the spinal cord had only been damaged on one side. A disorder of the spinal cord cannot be formally excluded, but we found no radiological evidence to support it.

Tsuzuki et al[18,34] have suggested that the pathology of C5 palsy includes some impairment of the C5 nerve root. Using cadavers, they demonstrated that impingement of the nerve root occurs inside the intervertebral joint with backward shifting of the spinal cord after laminoplasty. Furthermore, the superior articular process of C5 protrudes in a more anterior direction than at other levels and the rootlets and root of C5 are shorter than those of other segments and the C5 segment is usually the point at which the extent of posterior shift of the cord is greatest. For these reasons, C5 nerve root impingement might easily occur after laminoplasty. However, radiological evidence of nerve root impingement has not been obtained in previous studies because of the small number of cases and the mixing of patients with C5 palsy who had paralyses of other nerves. In our study, the significantly greater posterior shift of the spinal cord in patients with a C5 palsy indicated tethering of the nerve root, which might be made worse by the tendency of the bony gutter to adopt a more lateral position in these patients. The CT findings also support this argument. We found that cases of C5 palsy accompanied by pain in the distribution of the C5 root accounted for about 80% of those in which impairment of the root was suspected clinically. This suggests that it is more likely to be C5 impairment rather than spinal cord pathology. On this basis, the identification on pre-operative CT of a C5 root that is highly susceptible to injury may be predictive of a C5 palsy after laminoplasty.

There is no reliable way of preventing a C5 palsy, but its occurrence may be lessened by the selective use of concomitant foraminotomy after pre- or intra-operative electrophysiological tests.[35-38] The pathology of the palsy may be multifactorial, but if a patient has a stenotic C4-5 intervertebral foramen and a prominent articular process, a palsy may be avoided by carrying out a concomitant foraminotomy. Excessive expansion by laminoplasty should be avoided to prevent the C5 nerve root becoming tethered by a posterior shift of the spinal cord.

Spontaneous recovery from a C5 palsy has been recorded,[19,30,39] but motor paralysis (33%; 14 of 43) and pain in the upper extremity (18%; 6 of 34) were present at final follow-up in some of our patients, making it difficult to conclude that a satisfactory recovery had been achieved with conservative treatment. As a significantly worse recovery occurred if the patient was severely paralysed at the onset (mean MMT score in deltoid = 1.2 (0 to 2)), conservative treatment may not be indicated for such cases. An additional foraminotomy at an early stage should be considered in those with a severe paralysis or unbearable pain.

A C5 palsy does not appear to be associated with the type of laminoplasty, sagittal alignment of the cervical spine, or the presence of a high intensity area in the spinal cord. We have demonstrated impairment of the C5 nerve root on CT scanning. Stenosis of the C4-5 intervertebral foramen and prominence of the superior articular process

of C5 on pre-operative CT are predictive factors for the development of a palsy. Significant posterior shift of the spinal cord from excessive expansion can easily lead to such a lesion. Foraminotomy may be useful to treat patients with a C5 palsy and severe pain or motor paralysis (MMT = 0 or 1), even after laminoplasty.

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Supplementary material

Graphs showing the posterior shift of the spinal cord on MRI was significantly greater in group P, ‡the width of the C5 intervertebral foramen was narrowest on the paralysis side, †the anterior protrusion of the C5 superior articular process was most prominent on the paralysis side and the position of the bony gutter in group P tended to be more lateral than that in group C, but there was no significant relationship between the position of the bony gutter and development of C5 palsy and a figure showing an example of how we adjusted the radiographs for actual length are available with the electronic version of this article on our website at www.jbjs.org.uk

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