



ORIGINAL ARTICLE

An anatomical study of the different neurosurgical approaches of the cervical spinal cord

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Abstract

Introduction: There has been long standing controversy about the best approach for the cervical spinal cord, however there is no doubt that the clinical indication and the surgical procedure required will determine for most cases the best surgical approach.

Objective: This study was done to study the feasibility of the various neurosurgical approaches of the cervical spinal cord.

Methods: Ten cadaveric specimens obtained from the dissecting room of the Faculty of Medicine, University of Alexandria were dissected both anteriorly and posteriorly in the cervical region to compare between the anterior and posterior approaches for the cervical spinal cord and to identify the various anatomical structures met with during both approaches. Also various techniques of laminoplasty and laminectomy with lateral mass screw fixation had been performed.

Results: A posterior midline incision cuts through the skin, subcutaneous tissue, trapezius fascia and liqamentum nuchae, bilateral subperiosteal dissection of cervical paraspinal muscles. Keyhole laminoforaminotomy was done by removing the lateral portion of two adjacent laminae to expose foraminal course of the nerve root. Unilateral open door laminoplasty was done using non absorbable sutures, bone graft, or plate and screws. Then the laminae and spinous processes were cut in the midline with either drill or Gigli saw and opened bilaterally, then the defects were filled between the separated laminae by bone grafts and fixed by sutures (bilateral open door laminoplasty). Laminectomy was done to expose the dura mater and the cervical spinal cord. In lateral mass screw

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fixation the screw entry point was located 1 mm medial to the center of each lateral mass. The screws were directed 20° superior and 30° lateral to the screw entry point. The average screw length that can be used for bicortical fixation without injuring the vertebral artery or nerve root was about 13.5 mm and average screw thickness was about 3.5 mm.

After making an anterior incision through the skin and the investing layer of deep cervical fascia, the strap muscles were exposed. The sternomastoid muscle appeared on the lateral side of the neck with the carotid triangle between it and the strap muscles. After peeling off longus colli from the cervical vertebrae, their bodies and the intervening intervertebral disks can be seen. Partial corpectomies and anterior discectomy of the vertebral body and the intervertebral disk was done to expose the dura mater and the cervical spinal cord using either drill or Kerrison rongeurs.

Conclusion: The choice of the surgical approach to the cervical spine should be dictated by the site of the primary pathology. Cervical laminoplasty is an alternative to standard laminectomy allowing for a reasonable decompression of the vertebral canal with preservation of the supportive function of the vertebral column posteriorly. For a posterior approach to be successful the cervical lordosis should be intact and if affected the laminectomy must be combined with lateral mass screw fixation. The anterior approach has technical advantage that the decompression, fusion and immediate stabilization can be performed through one exposure, at one operation.

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1. Introduction

Various surgical approaches to the cervical spinal cord have developed as the clinical syndromes, mechanism of disease and pathological changes that ensue have been better defined.¹

A posterior approach is the traditional method, and has been the standard route by which the cervical canal and its contents are approached.² It includes laminectomy, hemilaminectomy, Keyhole laminoforaminotomy and laminoplasty and is indicated where a myelopathy and radiculopathy coexist, as foraminotomy at one or several levels can be combined with laminectomy. The goal of the foraminotomy is the early relief of brachial neuralgia and neurologic symptoms such as paraesthesiae.^{3,4} Cervical laminectomy provides access to the vertebral canal for a number of other conditions including syringomyelia, intradural tumors which may be intramedullary or extramedullary, or extradural tumors.⁵ Cervical laminoplasty is an alternative to standard laminectomy whereby the vertebral canal is enlarged without complete removal of the spines and laminae. The indications for laminoplasty include patients with spondylotic cervical myelopathy and the technique has been advocated for younger patients with spinal cord tumors.^{6,7} A variety of techniques have been reported including Z-shaped, unilateral and bilateral open door laminoplasty.⁸ Keyhole laminoforaminotomy is indicated in posterolateral disk prolapse.⁹ The disadvantages of the posterior approach include the possibility of causing instability, although this is unlikely if the integrity of the facet joints is preserved, and the failure of the technique to enable easy access to anterior structures.¹⁰ For a posterior approach to be successful the cervical lordosis should be intact and if affected the laminectomy with lateral mass screw fixation is an alternative.³

Anterior techniques for cervical cord decompression were first developed in the 1950s to address the poor clinical results and the late difficulties of posterior laminectomy procedures.⁴ Post-laminectomy instability with kyphosis and the ineffectiveness of posterior cord migration as a decompression method in the setting of anterior compression were felt to explain the poor results of posterior surgery for compressive myelopathy.¹¹

The anterior and anterolateral approaches to the cervical spine expose the anterior aspects of the cervical vertebral bodies and intervening intervertebral discs, they are most useful for anterior cervical cord and nerve root decompression through excision of herniated discs, tumors and vertebral corpectomies.¹²⁻¹⁴ They allow exposure of all levels and proper positioning of patients is a key point to give good operative exposure and prevent complications of excessive pressure on neural or vascular structures.¹⁵

Many anatomical structures must be handled carefully during this approach as the sternomastoid and omohyoid muscles, the carotid sheath containing the common carotid and internal carotid arteries, the internal jugular vein and vagus nerve, the 2nd part of the vertebral artery, the superior thyroid artery, the superior laryngeal and phrenic nerves as well as the cervical sympathetic chain, the larynx, trachea and esophagus.¹⁶

The posterior approach has several advantages over the anterior approach because the posterior midline structures can be rapidly and safely divided without endangering major vessels or nerves, the trachea or the esophagus and it is especially useful for decompression of multilevel stenosis and open reduction and stabilization of fracture dislocations.⁶ This approach should take place in the midline to avoid injury of the greater occipital nerve lateral to the external occipital protuberance in the roof of the suboccipital triangle, the posterior arch of atlas should not be exposed more than 1.5 cm from the midline because of risk of injury to the 3rd part of the vertebral artery and the suboccipital nerve.⁷

Aim of the work was to study the feasibility of the various neurosurgical approaches of the cervical spinal cord.

2. Methods

Ten cadaveric specimens obtained from the dissecting room of the Faculty of Medicine, University of Alexandria were dissected both anteriorly and posteriorly in the cervical region to compare between the anterior and posterior approaches for the cervical spinal cord and to identify the various anatomical structures met with during both approaches. Also various

techniques of laminoplasty and laminectomy with lateral mass screw fixation had been performed.

3. Results

3.1. Anterior and anterolateral approaches

After making an incision through the skin and the investing layer of deep cervical fascia, the strap muscles (infrahyoid muscles) including the sternohyoid and superior belly of omohyoid in a superficial layer and the thyrohyoid and sternothyroid in a deep layer appear covering the larynx and trachea at the front. The sternomastoid muscle appeared on the lateral side of the

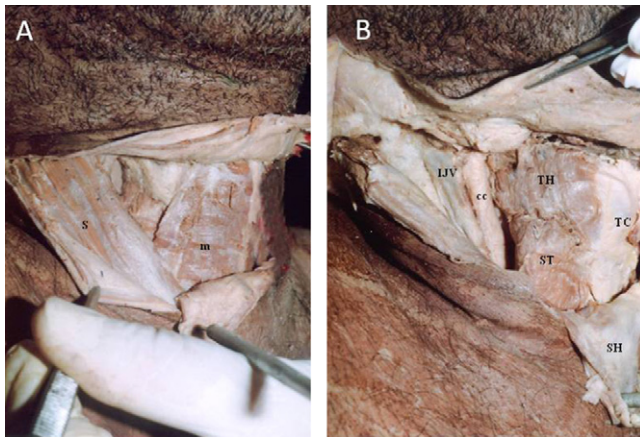


Figure 1 A photograph of the right anterolateral part of the neck showing: (A) the strap muscles (m) and the sternomastoid muscle (S); (B) the common carotid artery (CC), the internal jugular vein (IJV), the thyroid cartilage (TC), the thyrohyoid muscle (TH) and the sternothyroid muscle (ST) covering the right lobe of the thyroid gland. The sternohyoid muscle (SH) is cut and reflected downwards.

neck with the carotid triangle between it and the strap muscles, the carotid sheath containing the common carotid and internal carotid arteries medially, the internal jugular vein laterally and the vagus nerve in between and the sympathetic chain behind it (Fig. 1A and B).

The thyroid cartilage was protracted forwards and the longus colli muscles covering the front of the vertebral bodies were identified and dissected (Fig. 2A).

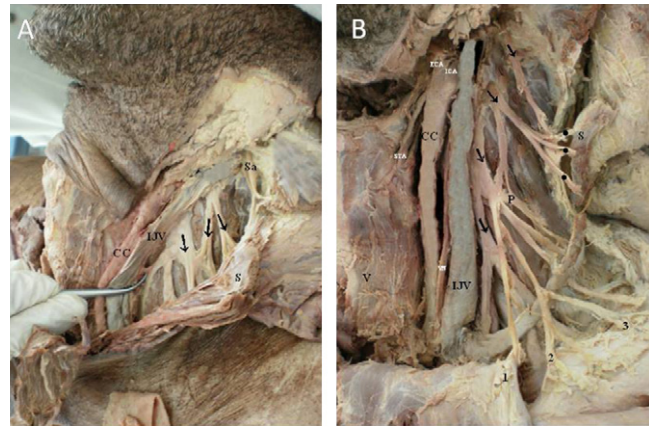


Figure 3 A photograph of the left side of the neck showing: (A) the common carotid artery (CC), the internal jugular vein (IJV), the spinal accessory nerve (Sa) and the nerve roots forming the cervical plexus pointed by arrows. The sternomastoid muscle (S) is reflected laterally; (B) the cervical vertebrae (V) appear at the front, the common carotid (CC), external carotid (ECA) and its superior thyroid branch (STA) and internal carotid (ICA) arteries, and the internal jugular vein (IJV) lateral to them and the vagus nerve (VN) in between and more laterally, the cervical nerve roots (pointed by arrows) forming the cervical plexus (P) and giving the supraclavicular nerves: medial (1), intermediate (2) and lateral (3); the proprioceptive branches (●) to sternomastoid muscle (S) can be seen.

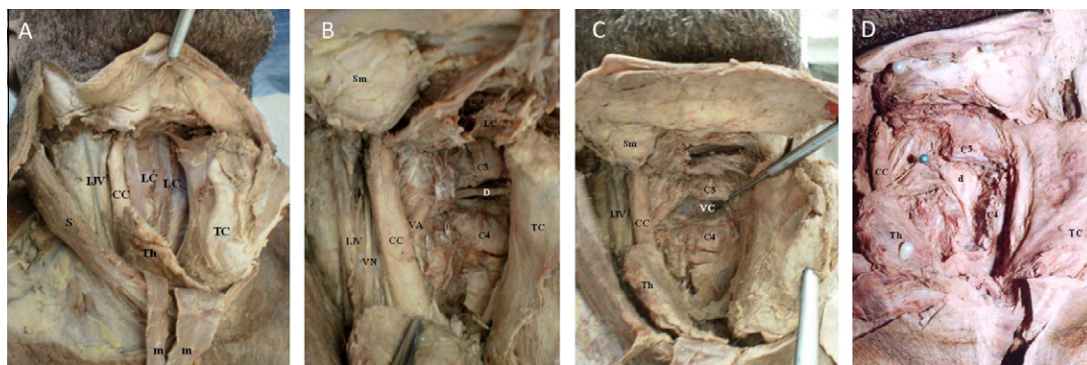


Figure 2 A photograph of the anterior part of the neck showing: (A) the sternomastoid muscle (S) is reflected laterally to the show the internal jugular vein (IJV), the common carotid artery (CC), and longus colli muscles (LC). The thyroid cartilage (TC) is reflected anteriorly and the strap muscles (m) are reflected downwards. Note the right lobe of the thyroid gland (Th); (B) after peeling off the longus colli muscle (LC) from the anterior aspect of the vertebrae and reflecting it upwards to show the bodies of C3 and C4 and the intervertebral disk (D) between them. Note the common carotid artery (CC), the internal jugular vein (IJV), the vagus nerve (VN) and the thyroid cartilage (TC), the submandibular gland (Sm), and the vertebral artery (VA) passing through foramina transversoria; (C) after anterior discectomy of the intervertebral disk between C3 and C4, the needle is pointed inside the vertebral canal (VC); (D) partial corpectomy of the bodies of C3 and C4 is done to show the dura mater (d) covering the anterior part of the spinal cord. Note the common carotid artery (CC), the thyroid cartilage (TC) is reflected anteriorly and the right lobe of the thyroid gland (Th) is reflected laterally.

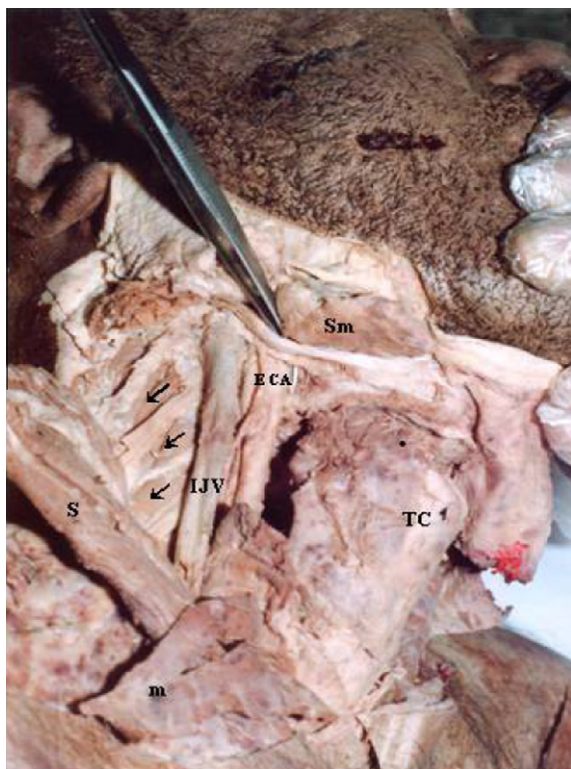


Figure 4 A photograph of the right anterolateral part of the neck showing the hypoglossal nerve pointed by the forceps and crossing the external carotid artery (ECA). The internal jugular vein (IJV) is present lateral to the artery, the sternomastoid muscle (S) is reflected laterally and the muscles in the floor of the post Δ are pointed by arrows. The thyroid cartilage (TC) is present anteriorly. The strap muscles (m) are cut and reflected downwards. Note the submandibular salivary gland (Sm).

After peeling off longus colli from the cervical vertebrae, their bodies and the intervening intervertebral discs could be seen, also the 2nd part vertebral artery passing through foramina transversoria of the upper six cervical vertebrae was shown (Fig. 2B). Partial corpectomy and anterior discectomy of the vertebral bodies and the intervertebral disk was done to show the dura mater and the cervical spinal cord using either drill or Kerrison rongeurs (Fig. 2C and D).

The superior thyroid artery could be identified and care must be taken not to injure this artery because it is often accompanied by the superior laryngeal nerve. More laterally the cervical nerve roots emerging from the intervertebral foramina, the cervical plexus and its branches, as well as the spinal accessory nerve passing through and supplying sternomastoid muscle can be seen (Fig. 3A and B).

More superiorly, the hypoglossal nerve, descends hypoglossi (superior root of ansa cervicalis), the submandibular salivary gland, the external carotid artery and its branches, the upper cervical nerve roots, the superior cervical sympathetic ganglion and the intermediate tendon and posterior belly of digastric muscle appeared (Fig. 4).

3.2. Posterior approaches

A posterior midline incision cuts through the skin, subcutaneous tissue, trapezius fascia and liqamentum nuchae, followed



Figure 5 A photograph of the back of the neck, the back muscles (M) were dissected from the vertebrae and the spines (S) and laminae (L) can be seen.

by bilateral subperiosteal dissection of cervical paraspinal muscles (splenius, semispinalis capitis and cervicis and multifidis) (Fig. 5).

Keyhole laminoforaminotomy, the lateral portion of two adjacent laminae and the medial part of the facet were removed using drill and fine rongeur to expose foraminal course, axilla and shoulder of the nerve root, the lateral part of the disk was approached from beneath the axilla of nerve root.

Unilateral open door laminoplasty, a trough was created at the junction of the articular processes (lateral mass) and the laminae using either high speed drill or curved Leksell rongeur at one side. Another trough was created by removing the outer cortex and cancellous bone and it was important to preserve some of inner cortex of the laminae on the hinge side. The ligamenta flava at C2–3 and C7–T1 were removed, the laminae were raised by bending open hinges that were kept in position either by non absorbable sutures, bone graft, or plate and screws which passed through holes in the laminae, grafts, and lateral masses (Fig. 6). Bilateral open door laminoplasty, after exposure of the spinous processes and laminae, troughs for the hinges were created on both sides, the laminae were cut in the midline with either drill or Gigli saw and opened bilaterally, then the defects were filled between the separated laminae by bone grafts and fixed by sutures (Fig. 7). Laminectomy was done to expose the dura mater and the cervical spinal cord (Fig. 8).

Lateral mass screw fixation after laminectomy, the whole lateral masses and the roots of the transverse processes of each vertebra were exposed; the screw entry point was located 1 mm medial to the center of each lateral mass. The screws were directed 20° superior and 30° lateral to the screw entry point. The plate was positioned on the lateral mass and screws were

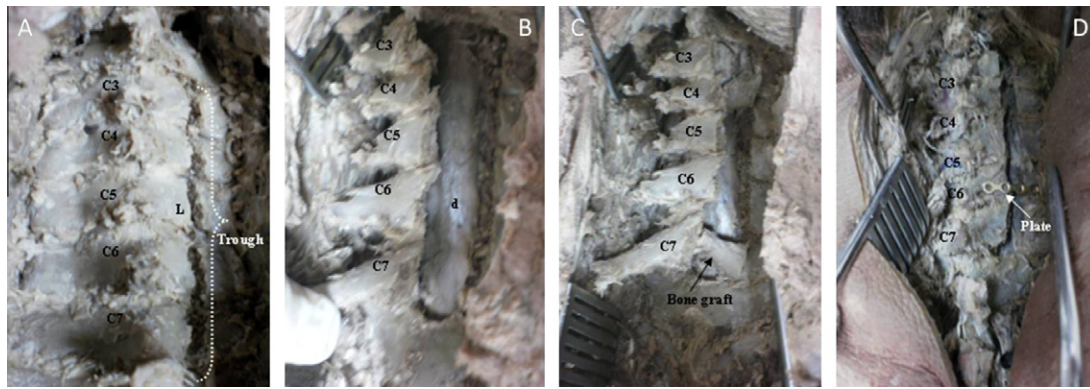


Figure 6 A photograph of the back of the cervical vertebrae showing steps of unilateral open door laminoplasty: (A) a trough was created at the junction of the articular processes (lateral masses) and the laminae (L); (B) the laminae were raised by bending open hinges, note the dura mater (d) covering the cervical spinal cord; (C) the laminae kept in position by bone graft; (D) the laminae kept in position by plate and screw.



Figure 7 A photograph of the back of the cervical vertebrae showing steps of bilateral open door laminoplasty: (A) the spinous processes (S) and laminae (L) were cut in the midline and opened bilaterally; (B) the defects between the separated laminae were filled with bone grafts and fixed by sutures.

inserted into the superior and inferior plate holes. The exit point of the screw is then located on the ventral aspect of the lateral mass just lateral to the posterior ridge of the transverse process (Fig. 9). The average screw length that can be used for bicortical fixation without injuring the vertebral artery or nerve root was about (13.5 mm) from C3 to C6, but at C7 it is only about 9.5 mm. The average screw thickness that can be used is ranging from 3.5 to 4 mm at any subaxial cervical vertebra. By applying lateral mass fixation in cadaveric specimens, depending on the resultant data mentioned above, it was clear that this technique can be applied clinically without any risk of injury to the vertebral artery, nerve root or facet joint.

4. Discussion

There has been long standing controversy about the best approach for the cervical spinal cord, however there is no doubt that the clinical indication and the surgical procedure required will determine for most cases the best surgical approach.¹⁷

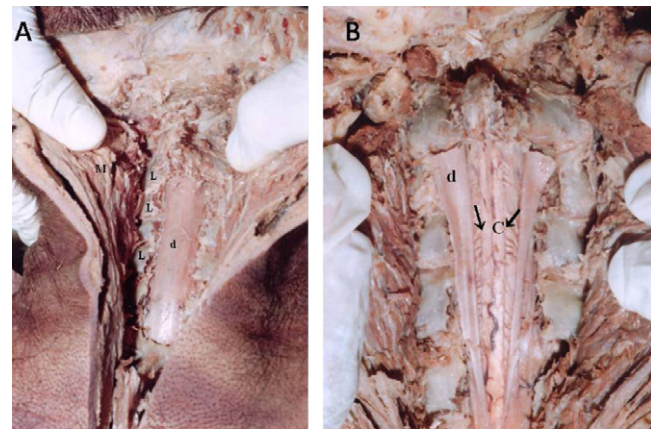


Figure 8 A photograph of the back of the neck showing: (A) the muscles (M) of the back cut in the midline and reflected laterally, the cervical spines and parts of the laminae (L) are removed (laminectomy) to expose the dura mater (d) covering the cervical spinal cord; (B) after opening the dura (d) in the midline and reflecting it laterally to expose the cervical spinal cord (C) and the posterior nerve roots (pointed by arrows).

From a pure anatomical point of view, it seems that anterior approaches are best for partial corpectomy and discectomy and that posterior approaches are best for laminectomy, laminoplasty, foraminotomy and the reason is obvious, it is the anatomical location of the body and the intervertebral disk anteriorly and the laminae posteriorly. The choice of the approach to the cervical spine should be dictated by the site of the primary pathology.^{18,19}

An anterior approach to the cervical spine is indicated where there is evidence of soft or hard disk prolapse causing myelopathy or myeloradiculopathy without significant posterior disease, where the disease is predominantly anterior (kyphosis or a degenerative subluxation), or for ossification of the posterior longitudinal ligament (OPLL).¹⁹ Segmental cervical instability should always be excluded preoperatively by functional X-rays with flexion and extension lateral views and if present, an anterior decompression and stabilization is preferred.²⁰

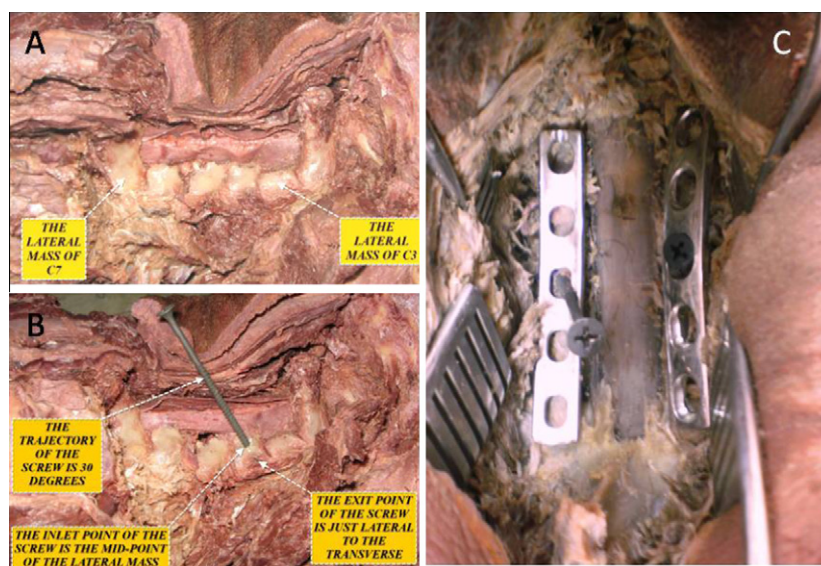


Figure 9 A photograph of lateral side of the cervical vertebrae showing: (A) Rt. lateral masses of the cervical vertebrae; (B) the screw being inserted 1 mm medial to the center of the lateral mass, oriented 20° superior and 30° lateral and its exit point just lateral to the transverse process; (C) the plate was positioned on the lateral masses and screws were inserted into the plate holes, note the dura mater (d) covering the cervical spinal cord.

The current popularity of the anterior approach is based on a variety of technical advantages that include improved clinical outcomes, a simplified surgical exposure, and the recognition that spinal instability may contribute to the pathophysiology of anterior cord compression. Wide decompression, fusion and immediate stabilization can be also performed through one exposure, at one operation, thereby avoiding the necessity for a concomitant posterior procedure.^{21,22}

Anterior approaches may cause neurologic complications as loss of sensation on the anterior surface of the neck, angle of mandible or the upper surface of shoulder due to injury to the cutaneous branches of the cervical plexus which may be damaged during routine anterior approach or if the sternomastoid has to be divided as they run across that muscle, sensation is usually restored within 1 year.²³ The marginal mandibular and cervical branches of facial nerve may be injured in high level disk exposure.²⁴ The recurrent laryngeal nerve may be injured in low level cervical laminectomy at C6–C7 or C7–T1 and causes hoarseness and weakness of voice, aspiration and respiratory obstruction. Superior laryngeal nerve is at lower risk, injury occurs at high level exposures and leads to loss of sensation above vocal cords which causes aspiration and paralysis of cricothyroid which leads to hoarseness and limits the ability to speak louder than at a conversational level.¹⁶ Hypoglossal nerve damage is unlikely to occur unless the dissection is carried superior to the digastric muscle and causes paralysis of ipsilateral side of tongue and deviation to the paralyzed side. Ansa cervicalis supplies strap muscles which depress the hyoid bone and elevate the larynx and its injury causes inspiratory disturbance. The cervical sympathetic trunk lies on longus colli muscle well away from the plane of dissection for cervical discectomy, if injured it causes ipsilateral horner's syndrome (miosis, ptosis and anhydrosis).¹⁵ Damage to nerve roots, dura and spinal cord are the most feared complications of cervical anterior approach, they are at risk when dissection is carried beyond the confines of the vertebral bodies

and disk space and can be prevented by adequate exposure, proper lighting, magnification, careful use of power, hand and instruments and thorough knowledge of what lies beyond the immediate plane of dissection. Nerve root and spinal cord injury are irreparable as are most dural tears, which can cause cerebrospinal fluid leakage.¹ Visceral injuries to esophagus are uncommon but serious even life-threatening.¹² Numerous veins and arteries can be ligated safely with the exception of internal jugular vein, common carotid artery and vertebral-artery. Middle thyroid vein at C5 level can be ligated. Superior thyroid artery in approaches above C4 can be ligated; care must be taken for superior laryngeal nerve that lies just posterior to the artery. Inferior thyroid artery at C6 level or below can be ligated lateral to the midline to avoid recurrent laryngeal nerve injury. Location of common carotid artery is identified by palpation in elderly patients who have compromised artery and who had multiple anterior procedures. Vertebral artery is not usually exposed in routine anterior exposure for cervical laminectomy however; it is in close proximity and may be injured, anomalous artery is in danger and may be injured during disk removal or if instruments are placed beyond the unco-vertebral joint.¹³

Until the 1950s, virtually the only operation for taking pressure off the cervical cord was cervical laminectomy. It is most commonly indicated in patients who have a compressive myelopathy with an associated effective cervical lordosis, here; decompression was achieved by removal of the spinous processes, associated ligaments, laminae, and a portion of the facet joints.²⁵ Unfortunately, adequate decompression requires the removal of important static and dynamic stabilizing structures.²⁶ Although good to excellent results have been reported, subsequent deterioration in outcome is not uncommon. Neurologic deterioration after laminectomy has been attributed to multiple causes, including the development of scar membrane around the dura, post-operative segmental instability, sagittal malalignment, and post-operative kyphosis.^{3,10} For a

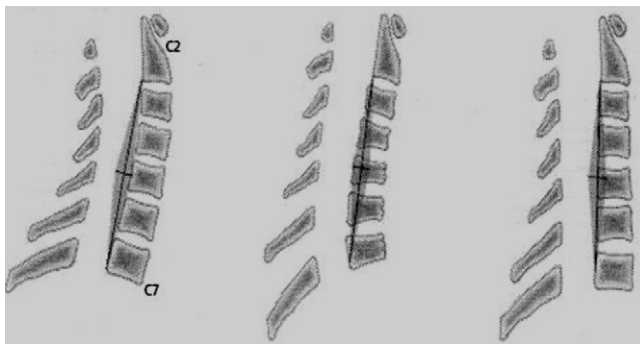


Figure 10 The choice of the surgical approach according to the presence of cervical lordosis or kyphosis: Gray zone is completely dorsal to the vertebral bodies, the spine is in lordosis, and a dorsal surgical approach is indicated (left). Gray zone is completely ventral to the dorsal aspects of the vertebral bodies, the spine is in kyphosis and a ventral approach is indicated (middle). Gray zone is partly dorsal to the dorsal aspects of the vertebral bodies, the spine is considered straight, and either approach is appropriate (right).³

posterior approach to be successful, the cervical lordosis should be intact. If the cervical lordosis is affected, the laminectomy with lateral mass screw fixation is an alternative (Fig. 10).³

In Japan, surgeons developed cervical laminoplasty after a high incidence of post-laminectomy deformity was encountered; it has become the treatment of choice in many countries.²¹ It is considered to be a recent method for surgical treatment of cervical canal stenosis, which was developed to widen the spinal canal dimensions and, in turn, to increase the cross-sectional area of the spinal cord without permanently removing the dorsal elements of the cervical spine. In 1973,

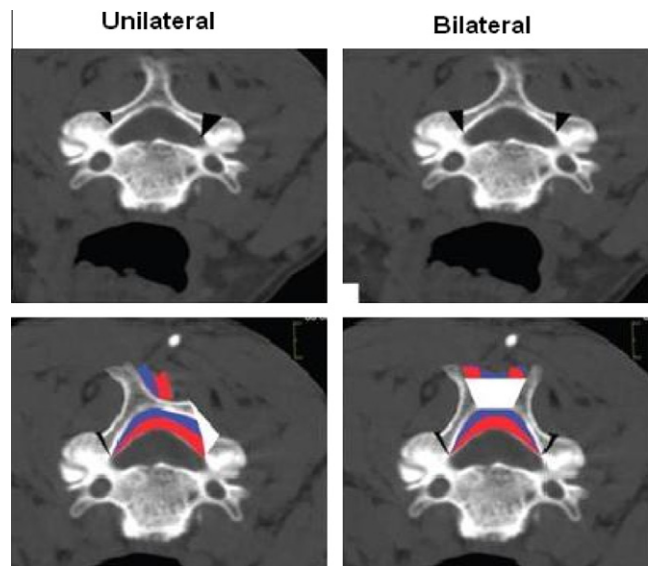


Figure 11 Cervical spine CT showing the difference between unilateral and bilateral cervical laminoplasty, also showing the widening of the spinal canal post-operatively.

Hattori et al.²⁷ described the first laminoplasty procedure, the canal expansive procedure involved a Z-plasty of each thinned lamina. With expansion of the modified lamina, complete reconstruction of the posterior arch was accomplished. In 1978, Hirabayashi²⁸ found posterior decompression could be achieved by lifting one side of the laminae without resecting the laminae totally. This technique is called unilateral open door laminoplasty. There are several modifications of open door laminoplasty using bone grafting, bone substitutes, or miniplates in the opened space. In 1982, a standard bilateral

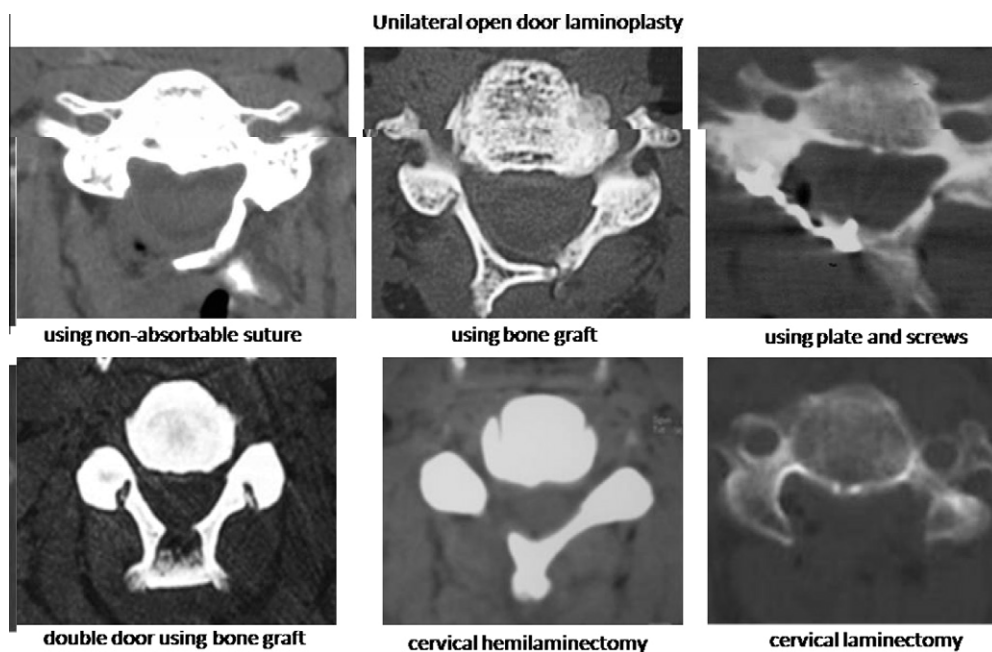


Figure 12 Axial cervical spine CT showing the different forms of unilateral open door laminoplasty, bilateral open door laminoplasty and the extent of bone removal after hemilaminectomy and laminectomy.

open door laminoplasty or the so called French door laminoplasty was introduced in order to replace laminectomy, to enlarge the spinal canal and decompress the cord.²⁹ Today these three fundamental expansive laminoplasty procedures (Z-plasty, unilateral open door, and bilateral open door laminoplasty) are commonly used, defined by where the hinge and opening of the lamina are developed, and how to keep the door open (Fig. 11).³⁰

The theoretical advantages of laminoplasty are: less anatomic disruption of the posterior elements while allowing for a reasonable decompression of the vertebral canal and preservation of the supportive function of the vertebral column posteriorly (Fig. 12).³¹ Of the varieties of laminoplasty, there is no general agreement regarding which one has clear advantage and longer term follow-up will be necessary to determine



Figure 13 Post-operative multislice CT with 3D reconstruction showing Lt. C6-7 laminoforaminotomy.

whether the method is indeed superior to the standard technique.³²

Posterior surgery by means of laminectomy, hemilaminectomy, foraminotomy and laminoplasty to expand the spinal canal is considered when three or more segments must be decompressed or when the stenosis covers most of the length of the spinal canal.^{33,34} For the congenitally narrowed canal, even minimal intrusions of osteophytes and hypertrophy of the investing ligaments may compromise spinal cord function.¹ Posterior cervical discectomy through a Keyhole laminoforaminotomy is suitable only in lateral disk herniation (Fig. 13).⁹

Lateral mass screw fixation has become the method of choice in stabilizing subaxial cervical spine among other posterior cervical fixation techniques whenever the posterior elements are absent or compromised.³⁵ The procedure represents an excellent option for the patient with facet dislocations that requires surgical reduction. It may also be used to stabilize pedicle or facet fractures by plating the lateral mass above and below the fracture.³⁶ It must be used after laminectomy if post-operative cervical kyphosis was expected (Fig. 14).

As with any operation, it is important to select the appropriate technique and tailor it according to each individual patient. Complications can be avoided with careful attention to details. The success of the operation ultimately depends on the surgeon's judgment, experience, and patient selection.²⁶

5. Conclusion

The choice of the approach to the cervical spine should be dictated by the site of the primary pathology. Neurologic deterioration after laminectomy is common and has been attributed to multiple causes, cervical laminoplasty is an alternative to standard laminectomy allowing for a reasonable decompression of the vertebral canal with preservation of the supportive function of the vertebral column posteriorly, and also it has been advocated for younger patients with spinal cord tumors. Plain X-ray is mandatory for detecting preoperative cervical instability, the cervical lordosis should be intact and if affected the laminectomy must be combined with lateral mass screw fixation. The anterior approach has technical advantage that the decompression, fusion and immediate stabilization can be performed through one exposure, at one operation.

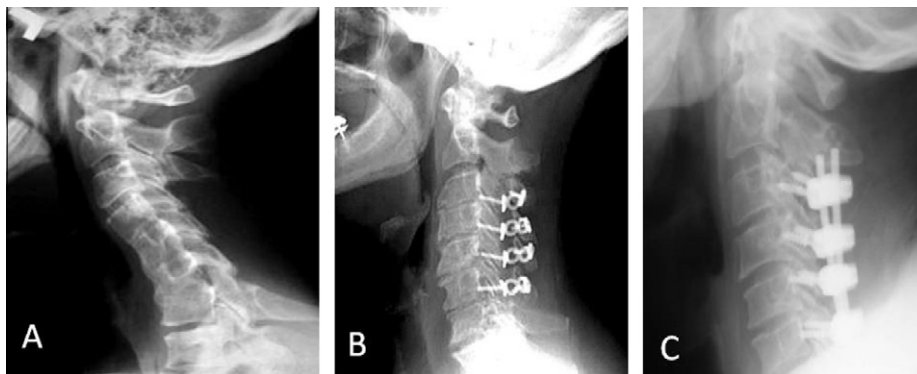


Figure 14 Plain X-ray lateral view of cervical spine showing the outcome of the different surgical techniques. (A) Post-laminectomy kyphosis; (B) post-laminoplasty; (C) post-lateral mass screw fixation.

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