Full-endoscopic cervical arcocristectomy for the treatment of spinal stenosis: results of a cadaver study

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Abstract

Purpose Cervical spondylotic myelopathy is a multifactorial disease that is directly correlated by the degree of spinal stenosis. Surgery remains the best therapy. A posterior approach is often recommended in patients with multilevel dorsal cervical compression. Aim of the present experimental study was to evaluate the feasibility of a full-endoscopic arcocristectomy in a cadaver study.

Methods We performed full-endoscopic arcocristectomy on ten formalin-fixed human cervical specimens. Before and after decompression we obtained high-resolution computerized tomography (CT) data to evaluate the diameter of the cervical spinal canal.

Results Overall, surgery was possible on 55 segments in ten cadaver specimens. A mean increase of 4.1 mm (± 1.2 mm) in the sagittal diameter of the cervical spinal canal could be achieved ($p < 0.05$, t test).

Conclusions The full-endoscopic arcocristectomy is feasible and achieves a sufficient decompression. This minimal invasive technique protects most of the dorsal structures and therefore probably preserves biomechanical functions, which has to be proven in future studies.

Keywords Arcocristectomy · Cervical spinal stenosis · Myelopathy · Endoscopic

Introduction

Cervical myelopathy due to congenital or acquired spinal stenosis, multilevel spondylosis and ossification of the posterior longitudinal ligament or yellow ligament occur in terms of absolute stenosis in younger patients in their forties and fifties, whereas relative stenosis is present more frequently between the ages of 50 and 60 [5]. Symptoms range from radicular irritations in terms of pain, palsy and numbness to painless myelopathy with upper and lower extremity weakness, numbness and loss of balance. Surgery remains the best therapy for patients under 65 years and patients with extensive clinical symptoms who are the main population considered for an invasive treatment strategy. The anterior approach was published, among others, by Cloward, and is suggested in patients with mainly anterior compression of the spinal cord [4, 10]. The posterior approach is often performed in case of primarily dorsal compression and in multilevel cervical compression whereat the decompression is usually extended two levels above and two levels below the maximum stenosis [5].

All dorsal procedures share the same disadvantage of a broad midline incision often carried out from C3 to the Th1 level. To avoid this large tissue trauma, minimally invasive procedures are currently used for one to three level laminectomy and foraminotomy in patients and cadaver studies [12, 14, 19]. We assume that minimally invasive approaches for extensive cervical stenosis with decompression on multiple levels including protection of stability of the posterior column can reduce narrowing of spinal cord and avoid kyphotic deformity with the need of posterior fusion procedure. Therefore, we evaluate the feasibility of full-endoscopic cervical arcocristectomy for the treatment of spinal stenosis in cadaveric specimens. In the technique of

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arcocristectomy, multiple partial superior laminectomies are performed to increase spinal canal diameter [2].

Materials and methods

The cervical spines of ten formalin-fixed human cadavers were used for this study. Full-endoscopic arcocristectomy was performed from C2 to Th1 on both sides.

To maximize standardization, the cadavers were fixed in a Mayfield skull clamp, which was connected to a transportable platform. The cervical spines were fitted on a wooden block at the end of the platform.

Preoperative and postoperative computerized tomography (CT) (Volume Zoom, Siemens, Erlangen, Germany) was performed in this standardized setting to evaluate the amount of bony decompression (slice thickness 1.5 mm). In accordance with Amaral et al. [1], sagittal diameter of the spinal canal was measured before and after resection of the superior half of the lamina (Figs. 1, 2). Therefore, the most comparable sagittal preoperative and postoperative CT-reconstruction images in each level were analyzed separately by two independent observers (SE and MK).

The access was selected under fluoroscopic biplanar guidance in the orthograde lateral and posterior anterior view based on anatomical landmarks. After selecting the point of entry through the skin (2 cm laterally from midline) and the incision (8 mm), the dilator (Vertebis cervical, Richard Wolf, Knittlingen, Germany) was introduced under lateral fluoroscopic guidance until it contacted the bone of the caudal lamina. The working sleeve was inserted over the dilator and the dilator was removed. The endoscope (Vertebis cervical, Richard Wolf, Knittlingen, Germany) was introduced through the working sleeve. The rod lens optic with an outer diameter of 6.9 mm and a length of 165 mm with a 25° angle of vision was used. The

optic contains an intraendoscopic, eccentric working channel with a diameter of 4.2 mm. The operation was performed under vision using bone punch, microrongeur, articulating bipolar radiofrequency electrode and a new actively articulating high-speed drill (Tipcontol, Richard Wolf, Knittlingen, Germany) under continuous irrigation. After dissection of the bony structures, the surgical procedure began at the caudal lamina. With the articulating high-speed drill, the upper half of the lamina was removed under preservation of the intraspinal ligament. Flavectomy, especially under the superior lamina, was followed. The decompression was completed after exposing the proximal portion of the nerve root on the ipsilateral side. The endoscope was removed and wound closure performed with one stitch. The procedure was resumed on the contralateral side. After the postoperative CT scan, a posterior midline incision was carried out and laminectomy was performed to explore and analyze the operative findings particularly the injury of the dural sac. Measurements were statistically compared using the student *t* test. A probability value (*p*) less than 0.05 was considered statistically significant.

Results

Overall, surgery was possible on 55 segments in ten cadaver specimens. Adequate preparation and CT evaluation were possible in all segments. A mean increase of 4.1 mm (± 1.2 mm) in the sagittal diameter of the cervical spinal canal could be achieved, whereupon the mean increase at the levels C5/6 (5.1 ± 1.2 mm) and C6/7 (6.0 ± 3.2 mm) was more pronounced than at the levels C3/4 (4.3 ± 1.6 mm) and C4/5 (4.2 ± 1.5 mm). Enlargement of the sagittal diameter at the cervical level C2/3 (2.3 ± 1.1 mm) and at the cervicothoracic junction (C7/Th1) (4.0 ± 4.4 mm) were at least distinctive (Fig. 3).

Measurements of the sagittal diameter after full-endoscopic cervical arcocristectomy showed a significant difference in comparison to the preoperative values ($p < 0.05$, *t* test).

Operating time for one segment (bilateral approach) was 26 min (range from 17 to 35 min). For decompression of five segments, two independent skin incisions were necessary. No injury of the thecal sac or nerve roots could be detected after performing laminectomy subsequent postoperative CT scan.

Discussion

Cervical stenosis with mild symptoms is often considered for a conservative treatment including steroidal and non-

Fig. 1 Illustration of the surgical bone removal of the upper half of the lamina and the resulting enlargement of the spinal canal ($B - A$)

Fig. 2 Preoperative (a) and postoperative (b, c) sagittal CT scans with successful enlargement of the cervical spinal canal. In b resection boundaries are graphically included

Fig. 3 Increase in the sagittal diameter of the spinal canal achieved in the different cervical levels

steroidal anti-inflammatory medications and a cervical collar. Surgery for patients with moderate to severe or progressive spondylotic myelopathy has been shown to result in significant improvement of pain and functional status in comparison to the conservative treatment [16]. However, the ideal surgical treatment option for cervical spondylotic myelopathy remains controversial. So far, published data could not report one surgical technique to be superior to others [6, 8, 9, 11, 13, 17, 18, 20]. The major disadvantage of posterior surgical approaches is cervical muscular pain due to an extensive dissection of the paracervical muscles from the spinous processes and laminae,

especially in multilevel maneuvers. In addition, the potential instability with risk of developing a deformity rises with the number of decompressed segments. Breig et al. first described the technique of arcocristectomy in order to prevent kyphotic deformity in patients with multilevel spondylotic myelopathy. In this technique, the upper half of the cervical laminae is removed to increase spinal canal diameter [2]. Amaral et al. [1] described 17 patients who were admitted for three to five level arcocristectomy. The sagittal spinal canal diameter improved significantly after surgery. Clinical postoperative findings were consistently good and formation of kyphotic deformity was not

described. Nonetheless, the disadvantage of extended surgical approach remains. To avoid the invasiveness of the above-mentioned approach different tubular or complete endoscopic procedures to the cervical spine have been introduced [3, 12, 15, 19]. Cervical disc disease is the leading indication for endoscopic foraminotomy according to literature. Microendoscopic decompression for cervical myelopathy has only been reported in a few cases, however with good or excellent results [12, 19]. In the published cases, a tubular retractor system with an inserted endoscope was used. The diameters of the tubes were between 16 and 20 mm [12, 14, 19]. The purpose of the current study was to show the technical feasibility of a full-endoscopic approach with more flexibility in combination with the above-described arcocristectomy in order to combine the advantages of both procedures. Focusing on the arcocristectomy the spinal sagittal diameter improved significantly in a mean of 4.1 mm. These results arise from the possibility of using an articulated endoscope with 25° angled lens in combination with an actively articulating high-speed drill. The high-speed drill allowed the surgeon to carry out effective resection of parts of the lamina or the entire lamina and parts of the facets using the interlaminar approach whereby the same enlargement of spinal diameter compared to the open arcocristectomy was achieved [1]. It could be demonstrated, that the enlargement in the lower cervical segments (C5/6 and C6/7) was considerably more than in the upper cervical segment and the cervicothoracic junction. This could be addressed to the increment of lamina caliber from cranial to caudal and the possibility of extensive bone removal without the risk of instability. Explanation for the lesser decompressive enlargement in the cervicothoracic junction could not be found. For open arcocristectomy, Amaral et al. mentioned a mean surgery time of 150 min (range from 110 to 300) for three to five segment. In the present study, decompression was performed in each segment on the left and right side with a mean surgery time of 26 min (range from 17 to 35 min) per segment, which is comparable or slightly faster. However, surgeons had a height experience in endoscopic spine surgery. The bilateral decompression via a unilateral approach is also conceivable with an additional time benefit. Furthermore, the full-endoscopic approach has the benefit of small skin incision (8 mm for the 6.9 mm endoscope) with a minimum of transmuscular dilatation when compared to a 16–20 mm tubular system or open surgery. Besides, the procedure is attractive because of the excellent visualization with the different kinds of endoscopes (15–30° angled lens). Not answered in this study is the influence of epidural bleeding to visualization and the ability of adequate control of hemostasis. Due to the fact, that the surgical procedure is performed under permanent irrigation with 0.9 % saline solution through separate

suction and irrigation channels and the bipolar radiofrequency coagulation of the venous plexus is possible, excellent visualization to perform hemostasis has to be assumed [19]. However, epidural vessels in spinal stenosis are capable of heavy bleeding and the possibility of epidural hematoma remains a complication of this procedure. The overall amount of blood loss can also not be evaluated but has to be supposed clearly under the amount of any open procedure and in the range of other endoscopic procedures to the cervical spine [19]. Regarding dural laceration, it is difficult to make any conclusive statements because thecal sac and spinal cord is distinctly different in a live patient. At postoperative inspection of the thecal sac, no dural laceration was found. This is in accordance with literature reports of endoscopic maneuvers [19].

In the case of multilevel spondylotic myelopathy the endoscope can be inclined cranially or caudally to reach adjacent levels. For five levels, two separate skin incisions are needed. The reduction to small incisions is described to minimize postsurgical pain and therefore hospitalization time, which also can be assumed in this procedure [7].

The full-endoscopic arcocristectomy is feasible and achieves a sufficient decompression of the spinal canal as detected by CT. This minimally invasive technique protects most of the dorsal structures of the cervical spine and therefore probably preserves biomechanical functions. This has to be proven in further studies.

Conflict of interest None.

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