Evaluation of the rate of decompression in anterior cervical corpectomy using an intra-operative computerized tomography scan (O-Arm system)

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Abstract

Object The purpose of this study was to evaluate the efficacy of intra-operative computerized tomography (CT) scanning in the analysis of bone removal accuracy during anterior cervical corpectomy, in order to allow any necessary immediate correction in the event of inadequate bone removal.

Methods From September 2009 to December 2010 we performed an intra-operative (CT) scan using the O-ArmTM Image system to assess the rate of central and lateral decompression in all patients treated for cervical spondylotic myelopathy by anterior cervical corpectomy and fusion.

Results Out of a population of 187 patients admitted to our department, with a diagnosis of myelopathy due to spondylotic degenerative cervical stenosis, 15 patients underwent a surgical treatment with anterior cervical corpectomy and fusion. There were nine males (60%) and six females (40%); the mean age was 52.4 years, ranging from 41 to 57 years. The pre-operative radiologic investigations (MRI and CT scans) revealed in the nine patients (60%) the extent of the compression to one vertebral body (C4 one case, C5 four cases, C6 four cases), while in the six cases (40%) the compression regarded two vertebral body (C3 and C4 one case, C4 and C5 two cases, C5 and C6 three cases). During surgery, when the decompression

was judged completely, a CT scan was performed: in 11 cases (73.3%) the decompression was considered adequate, while in four cases (26.7%) it was deemed insufficient and the surgical strategy was changed in order to optimize the bone removal. In these cases an additional scan was taken to prove the efficacy of decompression, achieved in all patients.

Conclusion Intra-operative CT scan performed during cervical corpectomy is a really useful tool in helping to ensure complete bone removal and the adequacy of surgery. The O-armTM Image system grants optimal image quality, allowing correctly assessing the rate of decompression and, in any case of doubt, allows an intra-operative evaluation of the final correct positioning of the graft.

Keywords Cervical corpectomy · O-Arm system · Myelopathy · Intra-operative CT · Decompression

Introduction

Cervical spondylotic myelopathy (CSM) is a common pathological entity, especially in the aging cervical spine [1–3], and is anatomically characterized by a degeneration of the cervical disk, osteophytic spurs, facets arthrosis, and ligamentous redundancy. These alterations finally lead to a reduction of the cervical spinal canal size [1, 4] and accordingly to dural and spinal cord impingement and compression. Although the treatment of cervical spondylosis is still not clearly defined [5, 6], the surgical treatment can effectively decompress the cervical spinal canal and achieve significant clinical improvement [7]. Despite the surgical approach is dictated by several factors [8, 9], the most natural approaches are the anterior ones, which range from anterior cervical discectomy with or without fusion

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(ACD or ACDF, respectively) to anterior cervical corpectomy with fusion [10–12].

To date, ACD and ACDF have been considered relatively simple approaches and are often the first choice for multilevel discarthrosis as well. However, when the extent of compression exceeds the osteophytic disk level, a corpectomy should be considered. Compared to ACDF, laminectomy and laminoplasty, patients treated with cervical corpectomy have a better neurologic recovery, and the outcome is directly correlated to the extent of bone decompression [13]. However, this approach is postulated as technically demanding and some authors also complain about the difficulty in obtaining sufficient decompression, both in a cranio-caudal direction and in the lateral portion of the vertebral body, as shown by post-operative CT scan [14]. For these reasons, different tools, such as ultrasonography [15, 16], three-dimensional fluoroscopy [14], and intra-operative CT scan [17] are proposed in order to control adequate bone removal intra-operatively.

In this study, we analyze the efficacy of an intra-operative computerized tomography scan performed with the O-ArmTM Imaging system in the evaluation of the correct bone removal during anterior cervical corpectomy.

Materials and methods

We analyzed the data of patients, admitted to our Neurosurgery Department from September 2009 to December 2010, with a diagnosis of CSM, surgically treated with anterior cervical corpectomy with fusion.

In our department the inclusion criteria for this approach are: severe cervical stenosis exceeding the osteophytic disc levels, instability of cervical spine at the level of stenosis, ossified posterior longitudinal ligament (OPLL), age less than 70 years old and mild or severe neurologic clinical picture (tetraparesis or tetraplegia). Moderate clinical presentation and cervical stenosis localized prevalently at disc level are considered contraindications, and ACDF is preferred.

All patients underwent a standardized pre-operative protocol of investigation, including MRI, CT and plain radiograph imaging, and assessment with Nurick and Japanese Orthopedic Association (JOA) scales.

A radiolucent operating table made of carbon was used for all patients. The surgical procedure was performed with a standard anterior approach with a right access. As microdiscectomy were performed at either end of the vertebral body (e.g., C4-C5 and C5-C6 to remove the C5 vertebral body), the corpectomy was performed using a high-speed drill with a diamond burr and completed with rongeurs and curettes. Finally, posterior ligament, and dorsal osteophytes were removed until sufficient decompression was achieved.

The adequacy of the decompression was evaluated during surgery using an intra-operative CT scan performed with the O-ArmTM Imaging system (Medtronic, Minneapolis, MN, USA): the completeness of bone removal was assessed directly by the operating neurosurgeon, reviewing the CT scan during surgery. If the bone removal was deemed inadequate, additional bone was removed selectively.

The defect was reconstructed with an autogenous iliac tricortical bone graft size, which depended upon the number of vertebrae removed and was fixed with plate and screws.

The scanning time with the O-ArmTM Imaging system was of about 13 s (normal definition) with the cervical protocol: 120 kVp (kilovolts peak), varying mA (milliamperes), 1 rotation, 391 pulses of 10 ms each (beam-on time 3.91 s per acquisition).

Results

From September 2009 to December 2010, a total of 187 patients were admitted to our Neurosurgical Department with a diagnosis of myelopathy due to spondylotic degenerative cervical stenosis. Of this population, 140 patients (74.9%) were treated with ACDF with the PCB cage [18], 32 patients (17.1%) with laminoplasty using titanium artificial-lamina [19] and 15 patients (8.0%) were treated with an anterior cervical corpectomy with fusion, and are the objects of this study.

There were nine males (60%) and six females (40%); the mean age was 52.4 years, ranging from 41 to 57 years.

In the nine patients, (60%) the extent of the compression was limited to one vertebral body (one case at C4 level, four cases, respectively at C5 and C6 level), while in the six cases (40%) it was of two vertebral bodies (one case at C3–C4 levels, two cases at C4–C5 and three at C5–C6).

Neurologic examination at admittance showed myelopathy signs (hyperreflexia, spasticity, extensor plantar response, bladder sphincter symptoms) in 14 patients (93.3%). The pre-operative JOA and Nurick scale are shown in Table 1.

The mean surgery duration was 90 min for a single level of corpectomy and 110 min for two. No additional morbidity and mortality occurred in the population. Intra-operative 3D scanning was carried out successfully for all patients. Scanning time was 13 s and the whole procedure from scanning to evaluation of the pictures never exceeded 3 min. The radiation exposure with the cervical protocol was of 120 kVp, 25 mA, 97.75 mAs, 12.41 CDTI (computed tomography dose index) while the dose length product (DLP) ranges from 85.4 to 198.55, according to the collimation used, which appreciatively correspond to 0.5–1.1 mSv.

Table 1 Pre-operative JOA score and Nurick scale

Scale	Patients (%)
JOA	
18–16	3 (20.0)
15–12	10 (66.7)
11–8	2 (13.3)
Nurick	
0	0 (0)
1	1 (6.7)
2	5 (33.3)
3	7 (46.7)
4	2 (13.3)
5	0 (0)

All spinal segments were visualized with good image quality, except for the first case: in this case the spreader was not removed and some artefacts were present (Fig. 1). However, it was possible to evaluate correctly the bony decompression. In all other patients the spreader was removed at CT scan time, with a final optimal image quality (Fig. 2).

In 11 cases (73.3%) the decompression was considered adequate, while in four cases (26.7%) it was deemed insufficient and the surgical strategy was changed so as to optimize the bone removal. In these cases, an additional scan was taken to prove the efficacy of decompression that was achieved in all patients.

Fig. 1 Axial view of intra-operative CT scan performed with the O-Arm™ system: the scan showed the persistence of a right-lateral osteophyte (red circle and white arrow). The presence of the spreader determined some artifacts with a final fairly good quality images

Discussion

As the incidence of CSM is increasing in the overall population, major interest regarding surgical approaches to treat this disease is increasing. The goal of surgery is to achieve a maximum decompression without compromising spinal stability. Therefore, anterior approaches are often preferred: in fact, there is a strong correlation between the extent of decompression of osteophytes, which are usually located anteriorly to the medulla, and the outcome [20, 21]. For this reason, cervical corpectomy, compared to ACDF, laminectomy and laminoplasty, have better neurologic recovery, with the final outcome directly correlated to the extent of bone decompression [13]. However, this approach is considered demanding for two main reasons. The first is related to the degree of pseudoarthrosis of the grafting (especially with long construct) and of the cage. The second concerns to the extent of decompression that is sometimes judged insufficient, as showed by post-operative CT scan, but often in these cases the indication of necessity for re-operation is seldom discussed and remains controversial.

For these reasons various technique to assess the adequacy of bone removal during anterior cervical surgery were proposed.

Goto et al. [15] used an intra-operative ultrasound system (IOUS) for confirmation of 16 mm or greater anterior trough decompressions. Also, Moses et al. [16] used the IOUS detecting a residual cord compression in six (27%) cases.

Instead, Hejazi et al. [22] used an intra-operative cervical epidurography. In 14 out of 39 patients (36%) this technique proved that the estimation of surgeons regarding resection completeness was incorrect. Albert et al. [23] addressed this problem by using a navigation system to monitor the adequacy of corpectomy. Freidberg et al. [17] used the Philips Tomoscan M (Philips Medical System, Eindhoven, The Netherlands), an intra-operative CT scanner, to evaluate the extent of resection and 17 (54.8%) out of 31 patients required further bone removal before wound closure.

Deinsberger et al. [14] used an Iso-C 3D fluoroscopy system (Siremobil Iso-C 3D; Siemens Medical Solutions, Erlangen, Germany), which allowed them to acquire and view multiplanar 3D images of intra-operative anatomy: in their series (seven patients) the operative strategy was changed in one case (14.3%) due to incomplete decompression.

In this study, the authors evaluated the accuracy of the O-Arm™ system in the assessment of bone removal during anterior cervical corpectomy. Out of the population, four patients (26.7%) required further decompression, due to the persistence of osteophyte (Fig. 1). In this case, that was the

Fig. 2 Intra-operative CT scan performed with the O-ArmTM system: axial (a), coronal (b) and sagittal (c) images showed the extent of the decompression, with an optimal image quality. The negative contrast

of the same examination (d–f) allowed to better optimize the visualization of bone residual

first in which we used the O-ArmTM system for this application, the quality of the images were fairly good due to the presence of the spreader that determined some artefacts. However, it was possible to visualize the extent of the decompression clearly as well as the presence of a lateral osteophyte (Fig. 1: red circle and white arrow). In all the other patients, the spreader was removed at CT scan time, with a final optimal image quality (Fig. 2). In particular, it was useful to control the extent of the resection not only in normal view (Fig. 2a–c), but also with a negative contrast (Fig. 2d–f), in order to optimize the visualization of bone residual. The complete process, from scan acquisition to surgeon evaluation, never exceeded 3 min. In the cases where more bone removal was judged necessary, an additional scan was taken to prove the efficacy of further decompression.

The overall radiation dose for the patient delivered by O-ArmTM system for cervical protocol is considerably reduced when compared with a standard CT scan. Smith-Bindman et al. [24] referred in their study, values of effective dose for a cervical CT scan ranging from 0.7 to 9 mSv, that are higher if compared with the doses revealed in our study (0.5–1.1 mSv).

However, also if the results obtained by this system are excellent, this technology, which combine a navigation system with an intra-operative CT scan, has a high cost (about \$750,000) that many facilities are not be able to afford. A cost-benefit consideration is thus mandatory. The main application field of this tool is represented by spinal arthrodesis surgery and allows a reduction of the surgical time [25] and of the costs of the pre- and post-operative CT scan. In particular, the reduction of surgical time allows an increased number of surgeries to be performed (up to 15% of spinal arthrodesis surgery/year), granting a final overall increased economic impact for the department (preliminary results, of an economic study that is presently being carried out in our Department). Moreover, the intra-operative CT scan, may be used for other neurosurgical application (i.e., for the control of bony removal in cervical and thoracic corpectomy and for the control of electrodes position in deep brain stimulation) reducing the final financial impact of this technology for the medical structure. These considerations, as well as the reduction of the rate of re-intervention (for misplaced screws, for incomplete bony decompression, etc.) may justify the costs of this technology in specialized Spine Units.

A review of the literature and our own results confirmed that an intra-operative 3D image system, if available, is a reliable tool granting a good rate of assessment of bone decompression and should be used in any patient operated on of CSM by an anterior cervical corpectomy.

Conclusion

This study demonstrates that the O-Arm™ Image system allows quick and accurate data acquisition for intra-operative CT for anterior cervical spine. The images, which are of good quality, may be used for the assessment of radiologic surgical results. Furthermore, this tool is effective in determining the completeness of decompression in anterior cervical corpectomy. The additional radiation dose is minimal and is clearly outweighed by a complete resection and thus offers a better long-term outcome, and does not require a post-operative CT scan. The technique is safe and reliable and allows doctors to avoid an incomplete decompression or eventually, if a final radiologic control is required, the misplacement of implants, therefore improving long-term functional outcome in cervical spine surgery.

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