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When does intraoperative 3D-imaging play a role in transpedicular C2 screw placement?

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ABSTRACT

Introduction: The stabilization of an atlantoaxial (C1-C2) instability is demanding due to a complex atlantoaxial anatomy with proximity to the spinal cord, a variable run of the vertebral artery (VA) and narrow C2 pedicles. We perfomed the Goel & Harms fusion in combination with an intraoperative 3D imaging to ensure correct screw placement in the C2 pedicle. We hypothesized, that narrow C2 pedicles lead to a higher malposition rate of screws by perforation of the pedicle wall. The purpose of this study was to describe a certain pedicle size, under which the perforation rate rises.

Patients and methods: In this retrospective study, all patients (n = 30) were operated in the Goel & Harms technique. The isthmus height and pedicle diameter of C2 were measured. The achieved screw position in C2 was evaluated according to Gertzbein & Robbin classification (GRGr).

Results: A statistically significant correlation was found between the pedicles size (isthmus height/pedicle diameter) and the achieved GRGr for the right (p = 0.002/p = 0.03) and left side (p = 0.018/p = 0.008). The ROC analysis yielded a Cut Off value for the pedicle size to distinguish between an intact or perforated pedicle wall (GRGr 1 or ≥2). The Cut-Off value was identified for the isthmus height (right 6.1 mm, left 5.4 mm) and for the pedicle diameter (6.6 mm both sides).

Conclusion: The hypothesis, that narrow pedicles lead to a higher perforation rate of the pedicle wall, can be accepted. Pedicles of <6.6 mm turned out to be a risk factor for a perforation of the pedicle wall (GRGr 2 or higher). Intraoperative 3D imaging is a feasible tool to confirm optimal screw position, which becomes even more important in cases with thin pedicles. The rising risk of VA injury in these cases support the additional use of navigation.

Introduction

Atlantoaxial instability may result from trauma, tumor, infection, arthritis or malformations and frequently requires surgical fixation. Due to a proximity to the spinal cord, thin C2 pedicles and a high variance in vertebral arteries (VA), stabilization of the disrupted atlantoaxial complex is still a surgically challenging procedure [1].

Goel [2] and later Harms [3] developed an individual stabilization technique for the treatment of atlantocervical instability. Via a dorsal approach polyaxial screws can be placed in the massa lateralis of C1 and pedicles of C2. Following a reduction maneuver the final alignement is fixed with two paravertebral rods.

Possible injury of the VA during screw insertion is a major risk of the Goel & Harms stabilization technique [4]. Pedicles width and isthmus height are determined by the anatomical course of the VA. A higher and more medial course of the VA in C2 may narrow the pedicles and leaves a smaller corridor for screw insertion. Therefore, it is obvious, that a high riding course of the VA increases the risk for malpositioning of respective screws significantly [4].

Although the risk of neurological deficit from VA injury has been calculated to be 0.2% per patient and 0.1% per screw, the consequences of such injuries may include brain infarction, massive bleeding and even death [4].

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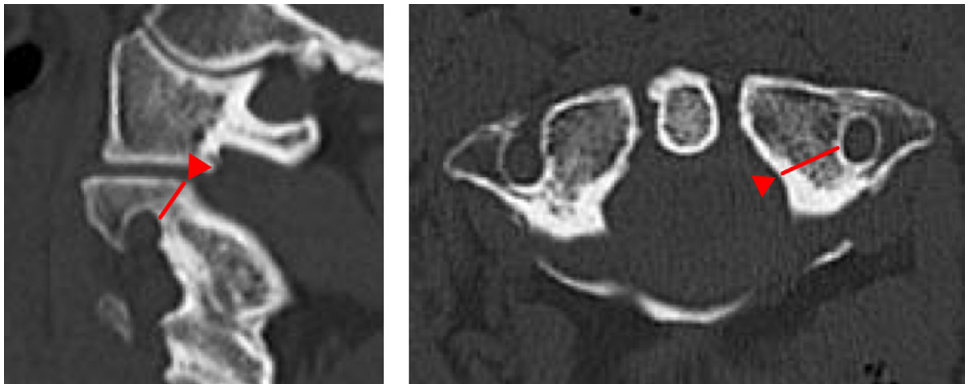

Fig. 1. Preoperative native CT scan of C2 to measure isthmus height and pedicle diameter.

In opposite to the postoperative computed tomography (CT) scans after stabilization of the cervical spine, a 3D scan may be an excellent tool to visualize the complex anatomical region intraoperatively and control the accuracy of screw positioning. Major advantage of this technique is the possibility of an immediate trajectory correction, if screw positioning is not optimal. Thus, revision surgery may be avoided, as malpositioned screws are not only seen on the postoperative CT scans.

Aim of the present study is a verification and correlation of intraoperative 3D scans with respective postoperative CT scans during routine clinical use in C1/C2 instabilities. We therefore analyzed a cohort of 30 patients with C2 pedicle screw fixation to define placement precision relying on the described techniques.

It was hypothesized, that narrow pedicles and a high riding VA lead to higher malposition rates by penetration of the pedicle wall. If so, could we specify a pedicle size, under which the malposition rate significantly rises? These circumstances would point up the importance of exact preoperativ planning and provide intraoperative 3D imaging to avoid malposition and complications in cases with thin pedicles.

Patients and methods

Patient selection

The following data was gathered within the scope of a retrospective clinical case series. All patients treated for atlantoaxial (C1/C2) instability at the Center for Musculoskeletal Surgery, Charité University Hospital Berlin (CVK) between 2010 and 2015 with the Goel & Harms technique were identified.

Inclusion criteria was the Goel & Harms technique with transpedicular C2 screw fixation, regardless of the cause for atlantoaxial (C1/C2) instability.

Epidemiological and surgical details were obtained from the patients' records in the clinical database. Prior to surgery, all patients presenting with an instable C1/C2 complex routinely recieved a cervical CT scan. Pedicle diameter and isthmus height (Fig. 1) as well as the course of the VA (Fig. 2) were assessed. In cases with severe neurological deficits a cervical magnetic resonance tomography (MRI) was performed prior to surgery to visualize the level of myelopathy.

Surgical technique

The patient is placed in prone position on a carbon table. Lateral fluoroscopy is used to verify alignment and positioning of the upper cervical spine. C1/C2 fusion was performed as described by Goel & Harms with positioning of bicortical 3.5 mm polyaxial screws bilaterally in C1 (massa lateralis) and C2 (pedicle). After insertion of the screws a routine intraoperative 3D scan (ARCADIS Orbic 3D, Siemens Healthcare, Erlangen, Germany) was performed to control positioning accuracy.

C2 screws then were rated according to Gertzbein & Robbins Grading (GRGr) [5]:

GRGr 1: fully within the pedicle
GRGr 2: perforating the pedicle wall <2 mm laterally
GRGr 3: perforating the pedicle wall >2 mm to <4 mm laterally
GRGr 4: perforating the pedicle wall >4 mm to <6 mm laterally
GRGr 5: perforating the pedicle wall >6 mm laterally

After implementation of the intraoperative 3D scan, the correct placement of the screws was confirmed in situ. If malpositioning was detected, the trajectory was immediately changed and the correct placement reassessed with another 3D scan. Postoperatively all patients routinely received conventional plain radiographs as well as a native CT scan to confirm surgical results. Atlantoaxial reduction as well as accuracy of screw positioning according to GRGr [5] was documented.

Statistical methods

Isthmus height and pedicle diameter were presented as mean and standard deviation, separated by GRGr left and GRGr right. They were tested for normal distribution using the Shapiro-Wilk test. We did not show any significant deviations from normal

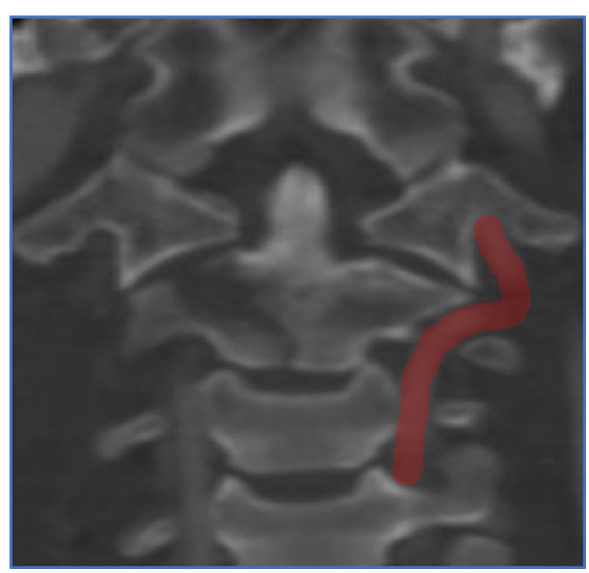

Fig. 2. Preoperative native CT scan of C2 with an Anderson Type 3 fracture to evaluate the course of the VA canal (colored).