Anatomical and computed tomographic analysis of C1 vertebra

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Abstract

Craniovertebral junction surgery requires knowledge regarding the anatomy of this region, particularly the C1 vertebra. Both C1 laminectomy and C1-2 instrumentation necessitate preoperative information about bony landmarks and the vertebral artery. This study compares the results obtained from anatomic and computed tomographic measurements of C1 bony landmarks. 31 C1 cervical vertebrae were measured; the C1 AP diameter, and C1 transverse diameter, the facet diameter, the distance between the anterior tubercle and the anterior aspect of the C1 lateral mass on a lateral view, the distance between the midline and the vertebral artery groove on the outer cortex of the posterior arch of C1 anatomically and computed tomographically. Anatomic measurements were performed by an anatomist using a Vernier caliper accurate to 0.1 mm, whereas the computed tomographic measurements were performed by a radiologist on bone window computed tomography (CT). The mean values and the differences between two measurement modalities were analysed using a paired t-test. There was no statistical difference between the results obtained by anatomical and radiological measurements for six parameters. There was, however, a statistically significant difference between two modalities regarding the distance between the midline and vertebral artery groove on the outer cortex of posterior arch of C1, while slightly different, the difference is within 1 mm and, therefore, not clinically significant. It is concluded that CT reflects most anatomical details of bony landmarks of C1.

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1. Introduction

Craniovertebral junction (CVJ) surgery is an important part of spinal surgery. It involves a variety of decompressive and stabilising procedures, requiring knowledge regarding the neurovascular and musculoskeletal anatomy of this region. C1 vertebra is an important part of the bony anatomy of CVJ. It has articular relationship with occiput and C2. The vertebral artery courses in the transverse foramen and on the vertebral artery groove of C1 lamina. This course of vertebral artery complicates surgical procedures in this area. On the other hand, C1 is the target of several fixation procedures, including C1-C2 transarticular screw fixation. This also necessitates knowledge regarding C1 bony landmarks [1,2]. The aim of this study was to find out the morphometric data regarding the bony landmarks of C1 vertebra and to compare the morphometric data with the computed tomographic one.

2. Materials and methods

Eight surgically important parameters regarding C1 vertebra anatomy were measured (Table 1 and Figs. 1–3).

Direct morphometric and computed tomography (CT) measurements of C1 vertebral anatomy relevant to surgery at this level were obtained from cadavers. The measurements were performed in 31 dry human C1 vertebrae. All the measurements were performed using a Vernier caliper accurate to 0.1 mm. After the anatomical
measurements, the same parameters were measured on axial, reformatted sagittal and coronal CT images of the 31 vertebrae. Sagittal and coronal images of the vertebrae were obtained by reformation of axial images on helical CT equipment.

The results of anatomic and radiologic measurements were compared using t-test and correlation matrix was calculated for all measured parameters.

3. Results

Table 2 lists the results of anatomic and computed tomographic measurements. The outer transverse diameter of C1 was measured as 74.7 and 74.9 mm, following anatomic and computed tomographic measurements, respectively. The outer AP diameter of C1 was measured as 43.2 and 43.3 mm, after anatomic and computed tomographic measurements, respectively. The distance between midline and vertebral artery groove on the outer cortex of C1 posterior arch, measured at 15.05 and 14.6 mm, respectively.

There was no statistically significant difference between anatomic and computed tomographic measure-
ments in six out of eight measured parameters. However, there was a statistically significant difference between anatomic and computed tomographic measurements in parameter number 4, i.e. the distance between midline and vertebral artery groove on the outer cortex of C1 posterior arch ($P > 0.05$). However, this difference was within 1 mm and it was not clinically significant. The other parameter which showed statistically significant difference was the AP diameter of superior surface of C1 anterior arch demonstrating the anatomical variation.

4. Discussion

The C1 vertebra has a unique anatomy. The lack of vertebral body and a ring-like shape differ C1 vertebra from the other cervical vertebrae. C1 ring consists of anterior and posterior arches, and two lateral masses with their superior and inferior facets. At the level of C1 vertebra, the vertebral artery exits the transverse foramen and course in the vertebral artery groove lateral to the spinal canal and posterior to the C1 lateral mass. In 1.2% of cases, there may be a bridge on the groove forming a foramen. The critical location of the vertebral artery may complicate decompressive procedures in this region. The risk of vertebral artery injury during surgery in this region has been addressed by some authors [1,2].

On the other hand, C1 vertebra is also the target of stabilisation procedures, including transarticular C1–C2 screw fixation procedure. In addition to need for information regarding the location of vertebral artery, this surgery requires knowledge regarding the distance of C1 anterior arch demonstrating the anatomical variation.

Table 1
The measured parameters on C1

<table>
<thead>
<tr>
<th>Parameter Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Outer AP diameter of C1</td>
</tr>
<tr>
<td>2</td>
<td>Inner AP diameter of C1</td>
</tr>
<tr>
<td>3</td>
<td>Outer transverse diameter of C1</td>
</tr>
<tr>
<td>4</td>
<td>Distance between midline and vertebral artery groove on the outer cortex of C1 posterior arch</td>
</tr>
<tr>
<td>5</td>
<td>Distance between C1 anterior tubercle and lateral mass in lateral view</td>
</tr>
<tr>
<td>6</td>
<td>AP diameter of C1 superior facet</td>
</tr>
<tr>
<td>7</td>
<td>Distance between outer margin of transverse foramen and outer margin of lateral mass</td>
</tr>
<tr>
<td>8</td>
<td>AP diameter of superior surface of C1 anterior arch</td>
</tr>
</tbody>
</table>

Fig. 3. The aforementioned measured parameters 1–8 are demonstrated on the CT scans.
between anterior border of C1 lateral mass and anterior tubercle on lateral X-ray view. This distance should be taken into consideration during C1–C2 transarticular screw fixation procedure. A too long screw may penetrate soft tissues anterior to C1 lateral mass.

Our results regarding anteroposterior and transverse diameter of C1 is parallel in line with the results of other studies reported by Doherty [3], Francis [4,5], and Williams [6]. The current study showed additionally the effectiveness of the use of CT for preoperative assessment of these parameters.

The other important parameter measured in this study is the distance between anterior border of C1 lateral mass and anterior tubercle on lateral X-ray view. As mentioned before, this parameter will contribute to detect the length of screw for transarticular fixation. This distance was found to be about 5 mm. On the other word, to avoid a soft tissue injury secondary to screw penetration, the tip of a transarticular C1–C2 screw which is targeted to anterior tubercle of C1 vertebra should be 5 mm behind the anterior border of anterior tubercle in lateral view of C-armed intensifier during operation.

Several authors addressed the importance of the location of vertebral artery groove during upper cervical spine surgery. Steifer recommended that the dissection of C1 posterior arch should stop 1 cm lateral to midline [2]. An and Simpson [1] also advocated that the posterior aspect of the C1 not be exposed more than 1.5 cm.

Recently, Ebrahim et al. [7], reported the distance between midline and vertebral artery groove on outer and inner cortex of C1 posterior arch. They reported the distance between midline and vertebral artery groove on the C1 posterior arch outer cortex to be 10 and 9 mm in male and female specimens, respectively. They also reported the distance between midline and vertebral artery groove on the C1 posterior arch inner cortex to be 17 and 19 mm in male and female specimens, respectively. Taking the minimum distances into consideration, they advocated that the dissection should remain 8 and 12 mm in the inner and outer cortex of C1 posterior arch. Our study found out this distance to be 15.03 ± 1.22 mm. This result is in line with the results reported by Ebrahim et al.

In summary, CT can be used as diagnostic tool for detection of C1 bony landmarks in preparation for craniovertebral surgery.

References