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Geometry of inferior endplates of the cervical spine

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ABSTRACT

Objectives: Device subsidence is a well-known complication following cervical disc arthroplasty. Its occurrence has been closely tied with the endplate-implant contact interface. But current literature on the geometry of cervical endplate is very scarce. The aim of this anatomical investigation was to analyze geometry of inferior endplates of the cervical vertebrae, thereby identifying the common endplate shape patterns and providing morphological reference values consummating the design of the implant.

Patients and methods: Reformatted CT scans of 85 individuals were analyzed and endplate concave depth, endplate concave apex location, sagittal diameter of endplate, coronal concave angle, as well as transverse diameter of endplate were measured in mid-sagittal plane and specified coronal plane. According to the endplate concave apex location, the inferior endplates in mid-sagittal plane were classified into 3 types: type I with posteriorly positioned apex, type II with middle situated concave apex and type III with anteriorly positioned apex. Moreover, the inferior endplates in specified coronal plane were also classified into three types: concave, flat and irregular.

Results: Based on visual assessment, for the mid-sagittal plane, type I endplate accounted for 26.9% of all the 510 endplates of 85 individuals, while the proportion of type II and type III endplates were 53.9 and 19.2% respectively. For the specified coronal plane, 68.6% of all the 510 endplates were evaluated as concave, 26.9% as flat and the remaining 4.5% as irregular. Among all measured segments, C3 had the largest endplate concave depth values in mid-sagittal plane, while C7 the least; C5 and C6 had the largest sagittal endplate diameter values, while C2 the least. For each level, the sagittal endplate concave depth and endplate diameter of females were significantly smaller than those of males ($P < 0.05$). Among all measured segments, C7 had the least coronal concave angle. Gender did not influence coronal concave angle significantly ($P > 0.05$). Increasing from C2 to C7, the endplate transverse diameters of females were significantly smaller than those of males ($P < 0.05$).

Conclusion: The exact shape and geometry of cervical endplate are crucial for the design and improvement of cervical disc prosthesis. Gender difference of sagittal and transverse diameters of cervical endplate should be given more attention when implanting a disc prosthesis. These endplate geometrical parameters should be taken into consideration when calculating most suitable geometric parameters of new disc prosthesis.

1. Introduction

Cervical disc replacement has been widely used in the treatment of degenerative cervical disc diseases. However, artificial cervical disc replacement may fail because of device-related complications, such as subsidence, heterotopic ossification, device wear and migration [1]. Subsidence is the most common complication following cervical disc arthroplasty with an incidence of 3–10% [1]. It is suggested that one desired artificial cervical disc should mirror the shape of both endplates of the same cervical segment in all three dimensions to gain a maximal contact area of the endplate-prosthesis interface [2]. Nevertheless, the endplate designs of those common cervical disc prostheses are oversimplified in contrast to the morphological complexity of vertebral endplates. That is to say, the profile of most currently available artificial cervical disc prostheses is limited to flat endplate or at the best minor convexity. This oversimplification of the design of cervical disc prosthesis would be bound to bring about insufficient contact area between endplate and disc prosthesis, finally resulting in subsidence of disc prosthesis.

The morphology of cervical endplate could have practical significance for cervical disc replacement. It has been demonstrated that

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endplate geometrics, such as the endplate concave angle and the sagittal or transverse diameter of endplate are crucial for artificial cervical disc design [3,4]. Besides, endplate shape has been related with clinical outcomes of cervical disc replacement [5]. Thus, the exact shape and geometry of cervical vertebral endplate could be of important clinical significance in the design and improvement of cervical disc prosthesis.

The purpose of this study was to analyze the sagittal and coronal geometry of cervical inferior endplates from C2 to C7 by employing processed data digitized CT scans. These messages were used to describe the common cervical endplate shape and consummate the design of cervical disc prosthesis.

2. Patients and methods

2.1. Patients

Eighty-five patients (average age 42 years, range 26–61 years) that underwent a cervical CT scans (Light Speed VCT, GE Healthcare, London, UK) were retrospectively selected from the Picture Archiving and Communication System (PACS). All the patients were scanned for head and neck symptoms and complained of no spinal problems. Scans with evidence of trauma, tumor, deformity or infection were excluded.

2.2. Images

All the CT scans images were imported into the Mimics 10.01 software to be multi-planar reformatted (slice thickness, 0.625 mm) and geometrical parameters were measured on the mid-sagittal plane (MSP) and specified coronal plane (SCP). MSP was defined as the image in which the complete contour of corresponding vertebral spinous process could be observed, while SCP was defined as the coronal plane intersecting the most concave point of the endplate on the MSP.

2.3. Visual assessments

The endplates on the MSP were visually classified into 3 types: type I with posteriorly positioned concave apex, type II with middle situated concave apex and type III with anteriorly positioned concave apex. The endplates on the SCP were also visually classified into 3 common shapes: concave if the central endplate was lower as compared to the epiphyseal rim, with an obvious curvature; flat if the central endplate and the epiphyseal rim were almost in the same plane without obvious curvature; and irregular if the endplate was rough or irregular.

2.4. Measurements

Anatomic landmarks, including anterior (A) and posterior (P) rims of the endplate on the MSP, left (L) and right (R) rims of the endplate on the SCP, as well as the most concave apex points (Ca, the endplate concave apex point in mid-sagittal plane and Cs, the endplate concave apex point in specified coronal plane) in both planes, were marked manually using the Mimics 10.01 software. Then, by using the same software, required angles and distances were measured. In drawing the perpendicular line from Ca to AP, one could get a point (Ca′) on the AP line, which could be regarded as the projective point of Ca in AP line and be very helpful in determining the location of endplate concave apex on the MSP. Coronal concave angle (CCA) was regarded as the obtuse angle formed by the rims (L and R) of endplate and the concave apex point (Cs) on the SCP. Besides, several other parameters were also measured, as follows: (1) endplate concave depth (ECD), which was the length of CaCa′; (2) endplate concave apex (ECA) location, namely the length of ACa′ divided by the length of AP; (3) sagittal diameter of endplate (SD), which measured the length of AP line; (4) transverse diameter of endplate (TD), which was the length of LR line (Figs. 1 and 2).

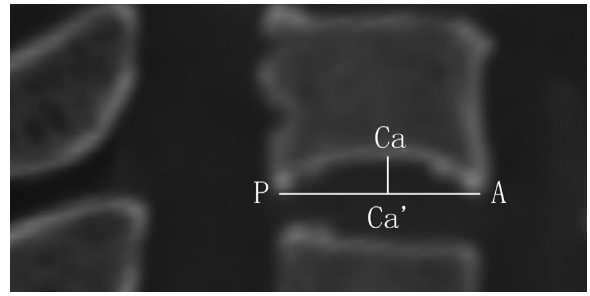

Fig. 1. landmarks in mid-sagittal plane: A—anterior rim of endplate; P—posterior rim of endplate; Ca—the endplate concave apex point; Ca′—the projective point of Ca on AP.

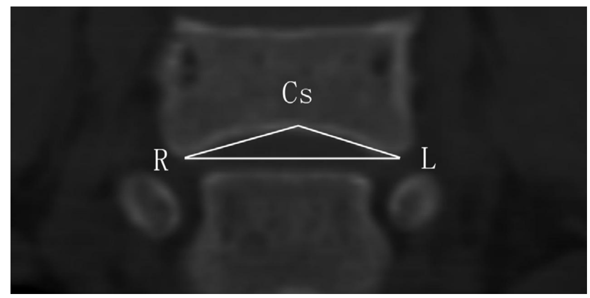

Fig. 2. landmarks in specified coronal plane: L—left rim of endplate; R—right rim of endplate; Cs—the endplate concave apex point.

Table 1
The distribution of different endplate shapes from C2 to C7 in mid-sagittal plane ($n = 85$, %).

	Type I	Type II	Type III
C2	20(23.5)	47(55.3)	18(21.2)
C3	12(14.1)	46(54.1)	27(31.8)
C4	28(33.0)	46(54.1)	11(12.9)
C5	21(24.7)	40(47.1)	24(28.2)
C6	19(22.4)	53(62.3)	13(15.3)
C7	37(43.5)	43(50.6)	5(5.9)
Total	137(26.9)	275(53.9)	98(19.2)

2.5. Statistics

The statistical program SPSS version 19.0 (SPSS Inc., for windows) was used for performing statistical analysis. Descriptive statics (means and standard deviations) were applied to quantitative variables. One-way analysis of variance (One-way ANOVA) and independent samples Student t test were employed for data analysis. Statistical significance was accepted at $P < 0.05$.

3. Results

3.1. The study of the anatomic geometry in the mid-sagittal plane (MSP)

3.1.1. Sagittal endplate shape

Based on visual assessment, for the MSP, type I endplate accounted for 26.9% of all the 510 endplates of 85 individuals, while the proportion of type II and type III endplates were 53.9% and 19.2% respectively. The proportion of different endplate shapes from C2 to C7 is present in Table 1.