A Novel Computerized Method for Measuring the Length of the Aorta in Patients with Severe Kyphotic Deformity

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Research article

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Abstract

Objective: This study aimed to explore a new method for measuring the length of the aorta in patients with severe kyphotic deformity.

Methods: The computed tomography (CT) scan data of one patient with severe kyphotic deformity were retrospectively collected. The data were saved as Digital Imaging and Communications in Medicine (DICOM) format, and were imported into MIMICS software for processing. Then, the MASK function of the MIMICS software was used to mark the aorta in each slice of CT, and a three-dimensional (3D) reconstruction model of the aorta was established. After that, the length of the aorta was defined as the length of the centerline, which was calculated by the MIMICS. Besides, two points were fixed as anchor, and the length of aorta was acquired by measuring the distance between the two points. The proximal one was the origin of the left subclavian artery, and the fork was the distal of iliac artery. The length of the aorta was measured preoperatively and postoperatively as well.

Results: The 3D reconstruction model of the aorta was successfully established. It was revealed that the length of aorta was 418.9 mm preoperatively, and 435.4 mm postoperatively. The patient also underwent pedicle subtraction osteotomy (PSO). After orthopedic surgery, the length of the aorta was stretched by 16.5 mm.

Conclusion: In the present research, a 3D reconstruction model of the aorta was successfully established, and the length of the aorta was accurately measured without any invasive procedure. Using MIMICS software, the length of aorta in patients with severe kyphotic deformity could be effectively and precisely measured.

Introduction

The spine kyphosis deformity is commonly complicated by the thoracolumbar kyphosis and/or lumbar lordosis or lumbar kyphosis, seriously influencing a patient's life quality [1, 2]. To our knowledge, osteotomy surgery is highly essential for such patients by lengthening the anterior column or/and shortening the posterior column, which is inevitable to stretch the aorta [3–5]. It is of great importance to study the changes in the aorta length in patients with severe kyphotic deformity with minor invasive procedures. However, previously conducted studies typically measured the aorta by two-dimensional (2D) images. Therefore, this study aimed to propose a new computerized method for measuring the length of the aorta in patients with severe kyphotic deformity.

Patients And Methods

This retrospective study was approved by the Institutional Review Board (IRB) of hospital. (Grant No: 51772328) All patients involved in the study consent to participate in the study, including the photographys. And the written consent has been obtained from all the patients. Computed tomography (CT) data of the chest and abdomen of one patient with severe kyphotic deformity were collected. The

data were collected by a CT machine (GE Healthcare, Chicago, IL, USA) available in Peking University People's Hospital (Beijing, China) for the thoracic and lumbar spine. The patient was placed in a supine position and remained neutral, and underwent CT scan that ranged from the T1 vertebral body to the lumbar vertebra L5.

Scanning conditions were as follows: bulb voltage: 140 kV, bulb current: 200 mA, layer thickness: 0.625 mm, image matrix: 512×512 . In addition, the gray scale of the CT image was adjusted. The contrast was changed, and the image details were processed to achieve a clear CT image. The CT scan raw data were saved as Digital Imaging and Communications in Medicine (DICOM) format.

Additionally, those data were imported into MIMICS 19.0 software for processing. The MIMICS software was run and the view direction was set to define the sagittal, coronal, and cross sections to save multiple DICOM data in an orderly manner (Fig. 1). With pre-processing the image, the resolution and smoothness can be improved, and the software also contains a selection tool for regularization. According to the different gray values of the tissue on different images, we attempted to set the corresponding gray threshold interval.

The CT window position was adjusted to make the density of the large blood vessels in image relatively obvious (Fig. 2), and the aortic shadow was calibrated using MASK function of the MIMICS software (Fig. 3). The aortic shadows of each layer were sequentially calibrated as well.

CT scan data of each layer were further precisely labeled with the aorta. As shown in Fig. 4, a three-dimensional (3D) reconstruction model of the aorta could be established with the help of MASK function of the MIMICS software. The patient's aortic model was also established by a function in the software (Fig. 5).

The centerline of the aortic model was estimated using the "centerline" of the "analysis objects" in the MIMICS, and the length of the centerline was measured to define the length of the aorta.

X-ray radiographic examination

The standard standing posterior-anterior and lateral X-ray film of the lumbar spine and whole spine were obtained. The radiographic assessment consisted of thoracolumbar kyphosis (TLK, T10-L2), lumbar lordosis (LL, L5-S1), sacrum slope (SS), and pelvic tilt (PT).

Results

Radiological results

The patient underwent pedicle subtraction osteotomy (PSO). The TLK decreased from 58.6° preoperatively to 23.8° postoperatively. The LL reduced from 83.1° preoperatively to 49.6° postoperatively. The PT attenuated from 35° preoperatively to 25.7° postoperatively. The SS increased from 25.9° preoperatively to 34.8° postoperatively.

The Length Of Aorta

The length of the aorta increased from 418.9 mm preoperatively to 435.4 mm postoperatively. After the surgery, the aorta was stretched by 16.5 mm (Figs. 7–8).

Discussion

The spine kyphosis deformity is mainly caused by congenial, tuberculosis, ankylosing spondylitis, fracture, etc. [1, 2, 12–17]. The lumbar osteotomies are appropriate surgical techniques to improve the global sagittal balance of the spine, increasing the lumbar lordosis and decreasing the pelvic (lower PT) and the femoral (lower femoral flexion) compensation. Vertebral column decancellation (VCD), a combination of the eggshell technique, Smith-Petersen osteotomy (SPO), PSO, and vertebral column resection (VCR), is highly appropriate for the majority of patients with severe rigid kyphosis [6–8, 18–20]. Regardless of the type of osteotomy surgery, the general principle is to lengthen the anterior column or/and shorten posterior column [3–5]. In order to achieve a high level of correction of deformity, lengthening the anterior column is of great importance, which may result in injury. The complication of aorta injury is rare in the procedure of spinal osteotomy for the correction of Pott's thoracolumbar angular kyphotic deformity.

Numerous previous studies have explored the changes of aorta after undergoing PSO. Weatherley et al. [9] reported patients with severe kyphotic deformity who underwent SPO. The corrected kyphosis angle was 45°, and the length of the aorta was stretched by 2 cm. Chang et al. [10] applied osteotomy in the treatment of kyphosis, and it was demonstrated that the aorta was lengthened by 2.8 cm (1.7–3.5). Ji et al. [11] reported that in case of osteotomy after the treatment of kyphosis, the length of the aorta was increased by 2.2 cm and the diameter of the aorta was decreased by 0.41 cm. Bourghli et al. [12] adapted a new surgical method of osteotomy to treat the angular kyphosis caused by fracture, and it was found that after surgery, the length of the aorta was increased by 2.3 cm. The above-mentioned studies indicated that due to elongation of the anterior column, the aorta may be stretched and vulnerable to injuries, especially in the elderly patients with reduced elasticity of the aortic wall. Once that is stretched seriously, the incidence of aortic injury increases. Besides, there is a relationship between the extension of the length of the aorta and the decrease of diameter of aorta, which may influence the hemodynamic. Therefore, vascular complications are required to be highly considered by surgeons.

Several scholars presented methods for measuring the length of the aorta. Chang et al. [10] used an atherosclerotic plaque to measure the change of the length of the aorta. Since no obvious calcification was observed in many cases, it therefore was not appropriate for all patients. Ji et al. [11] and Bourghli et al. [12] measured the length of the aorta between the instrumented vertebrae, and reported the changes in aorta. Although the aorta was fixed with aortic hiatus and branch vessel, the position of the aorta shifted with the change of body, indicating that their method is inaccurate. Besides, for the patient with angular kyphosis, the pathway of aorta is irregular and tortuous, therefore, it is difficult and inaccurate to

measure the length of the aorta using the above-mentioned methods. Hence, in the present study, we adapted a new method for measuring the length of the aorta in patients with angular kyphosis.

Firstly, we fixed two points as anchors and the length of aorta was obtained by measuring the distance between the two points. The proximal one was the origin of the left subclavian artery, and the distal was the fork of the iliac artery. As a result, the effects of modified aorta position on outcomes could be eliminated. Additionally, it is essential to acquire 3D image to accurately measure the length of the aorta. The most common approach in clinic is angiography, requiring injection of radio-opaque contrast agents. As performing angiography was dangerous for our patients with severe kyphotic deformity, we refused carrying out that examination. Alternatively, we used MIMICS software to establish a 3D reconstruction model of the aorta. This accurate method could measure the length of the aorta by measuring the length of the aortic diameter, without application of angiography, which could reflect the changes in the length of aorta.

Compared with previous methods described in the literature, the proposed method possesses a number of advantages as follows: firstly, for patients with severe kyphotic deformity, especially for patients with Pott's thoracolumbar angular kyphotic deformity, the aorta ran in different directions, and it was hence incorrect to measure each segment of the aorta by 2D images. However, we can determine the 3D reconstruction model of the aorta by using MIMICS software, resulting in a precise measurement. Secondly, patients with severe kyphotic deformity are commonly complicated by ischemia, therefore, angiography for such patients may be dangerous. With the help of MIMICS, the risk of ischemia is significantly reduced. In addition, the fixed two points can eliminate the effects of movement of the aorta caused by the correction of deformity.

Although the proposed method could be used in an invasive manner to measure the length of aorta, it still has some limitations. Firstly, the proposed method requires calibration of location of aorta for several times manually, demonstrating that the mentioned method is time- and energy-consuming. Furthermore, due to anatomical variations of patients with deformity, an experienced spine surgeon should measure its length to reduce the error.

Conclusions

For patients with severe kyphotic deformity, it is dangerous to undergo angiography to achieve a 3D image, and measuring the length of the aorta by a 2D image is an inaccurate method as well. In the present study, we successfully established a 3D reconstruction model of the aorta, and the length of the aorta was accurately measured without requiring an invasive procedure. The proposed method appeared as effective and safe to measure the length of the aorta in patients with severe kyphotic deformity.

Abbreviations

TLK: thoracolumbar kyphosis

LL: lumbar lordosis

SS: sacrum slope

PT: pelvic tilt

PSO: pedicle subtraction osteotomy

VCR: vertebral column resection

VCD: vertebral column decancellation

Declarations

Ethics approval and consent to participate

This retrospective study was approved by the Institutional Review Board (IRB) of all hospital. All patients involved in the study consent to participate in the study. And the written consent has been obtained from all the patients.

Consent for publication

All individual person's data consent to publish.

Availability of data and materials

Please contact author for data requests.

Conflict of interest

The authors declare that they have no conflict of interests.

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Figures

Figure 1

Figure 2

The arrow shows the level of the abdominal aorta bifurcation artery

Figure 3

Aortic shadow calibrated by MASK function

Figure 4

MASK calibration of the aortic full-layer and its 3D display

Figure 5

3D model of the aorta

Figure 6

Extracting the centerline

Figure 7

the length of the aorta(preoperative)

Figure 8

the length of the aorta(postoperative)