The pre-styloid compartment of the parapharyngeal space: a three-dimensional digitized model based on the Chinese Visible Human

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Abstract To build a digitized visible model of the parapharyngeal space of the Chinese Visible Human and to provide a sectional anatomic basis for radiological and clinical diagnosis of the parapharyngeal space, sectional anatomy data of the parapharyngeal space were selected from the Chinese Visible Human male and female to compare with MR imaging findings in the axial planes. From these data the parapharyngeal space and surrounding structures were segmented. They were then reconstructed in three dimensions on PC. In the axial planes of the sectional anatomy and MR imaging, the shape, content and relations of the parapharyngeal space were clearly displayed and the dominant plane for showing the parapharyngeal space was elicited. The three-dimensional reconstructed images displayed perfectly the anatomic relationships of the parapharyngeal space, parotid, muscles, mandible and vessels. All reconstructed structures can be displayed singly, in groups or as a whole; any diameter or angle of the reconstructed structures can be easily measured. The Chinese Visible Human male and female data set can provide complete and accurate data. The digitized model of the parapharyngeal space and its surroundings offers unique insights into the complex anatomy of the area, providing morphologic data for imaging diagnosis and surgery of the parapharyngeal space.

Keywords Visible human · Sectional anatomy · MRI · Parapharyngeal space · Computerized 3D reconstruction

Introduction

The parapharyngeal space (PPS) is the deep space of the head and neck, the adjacent relations of which are very complicated. The three-dimensional (3D) shape and complex spatial relations of the PPS cannot be completely demonstrated by traditional gross anatomy and sectional anatomy. It has been a difficult region for examination for a long time. In recent years, some authors have studied the PPS by radiological methods [1, 2, 3, 4, 8, 10, 13]. However, the PPS is a deep space of the neck and there are many soft structures around it, so it is a difficult region for the radiologist [7]. There have been few reports on 3D reconstruction of the deep facial space [5]. However, the 3D reconstruction of the PPS and its surrounding structures can help surgeons to understand the complicated deep facial space and select a suitable operative technique. The aim of this study was to explore the anatomic and radiological features of the PPS by comparing thin-sectional anatomic data from the Chinese Visible Human [11, 12] with the magnetic resonance imaging (MRI) findings, and to provide a sectional anatomic basis for radiological and clinical diagnosis of the PPS. Furthermore the digitized model of the PPS and its surroundings offers unique insights into the complex anatomy, providing morphologic data for imaging diagnosis and surgery of this area.
Materials and methods

Cryosection of specimens

Middle-sized, middle-aged male and young female cadavers without organic lesions verified by naked-eye observation were used. After vascular perfusion, the specimens were embedded in gelatin and then placed in a \(-30\,^\circ\text{C}\) saline pool for cryopreservation for 1 week, then in the laboratory at \(-25\,^\circ\text{C}\). The specimens were serially sectioned from head to foot layer by layer (sectioning accuracy: 0.001 mm) with a TK-6350 Digital Sectioner. The slice thickness was 0.5 mm and 0.25 mm. All the slices were serially photographed using a Canon digital camera with a resolution ratio of 3072\(\times\)2048. Each sectioned image file of 36 MB was input into a personal computer (PC). The shape, content and adjacent relations of the PPS were observed by enlargement on the computer.

MR imaging and comparative observation with cryosections

Before cryosectioning, the specimens underwent MRI on a 1.0 T Siemens Magnetom Impact system. Scan parameters were: T1 weighting, TR 580, TE 15.0/1, TA 6:58; 1.5 mm thick slices (without a gap) were acquired. The cryosections and MR images were compared and the findings recorded.

Computerized 3D reconstruction

Four plastic rods were placed in the mold parallel to the long axes of the cadaver before embedding. These rods were used as alignment signs for reconstruction. Subsequently the digital images were input into a PC and the location was corrected with four indicating signs. Next, the PPS and its surrounding structures were identified semi-automatically on a section-by-section basis and reconstructed with the software for 3D reconstruction designed and developed by our research group. Finally, the PPS and parotid gland, pharynx and mandible, etc., were reconstructed and displayed.

Results

In the Chinese Visible Human male and female data set, the serial digital images allowed a unique anatomic insight into the deep face, highlighting the subtle anatomic structures of the PPS and its adjacent structures with excellent distinction of connective tissue, bones, muscles, nerves and blood vessels. The PPS lies lateral to the pharynx. It has an inverted-pyramid-shaped space that extends from the skull base to the hyoid bone. The PPS is divided by the styloid process and styloid muscles into two compartments: the anterior or pre-styloid compartment, and posterior or post-styloid compartment. The pre-styloid compartment is filled with loose connective tissue, the ascending pharyngeal artery, pharyngeal vein, pterygoid venous plexus and mandibular nerve. The post-styloid compartment contains the internal carotid artery, internal jugular vein, vagus nerve, glossopharyngeal nerve, hypoglossal nerve, accessory nerve and lymph nodes. This article deals only with the pre-styloid compartment.

Transverse section through the foramen magnum

The level of the foramen magnum (Figs. 1, 2) is the layer at which the PPS appears first. At this level the PPS is a triangular space with its apex anterior, which lies adjacent to the nasopharynx. Lateral to the PPS, from anterior to posterior, are the lateral pterygoid, the ramus of the mandible and the deep lobe of the parotid gland. Its anterior wall is the medial pterygoid. Medially, it is bordered by the tensor veli palatini, the levator veli palatini and nasopharynx, and adjacent to the superior constrictor of the pharynx covering the pharyngeal recess. Posterior to the PPS is the prevertebral fascia. On MRI, the PPS has high signal intensity because of its predominant fatty content. Its anterior wall is the medial pterygoid with medium signal intensity. The medial wall of the PPS is the tensor veli palatini, the levator veli palatini with medium signal intensity, and the pharyngeal recess with low signal intensity. Laterally lies the lateral pterygoid with medium signal intensity and the ramus of the mandible with low signal intensity.

![Fig. 1 Transverse section through the foramen magnum. pps, Parapharyngeal space; 1, pharyngeal recess; 2, nasopharynx; 3, tensor veli palatini; 4, pharyngeal vein; 5, lateral pterygoid; 6, submandibular nerve and its branch; 7, pterygoid venous plexus; 8, deep lobe of parotid gland; 9, styloid process; 10, internal carotid artery; 11, medial pterygoid; 12, ramus of mandible](image-url)
Transverse section through the atlantoaxial joint

At the level of the atlantoaxial joint (Figs. 3, 4) the PPS shows a typical splayed shape that lies lateral to the oropharynx. Anterolaterally is the medial pterygoid. Posterolaterally is the deep lobe of the parotid. Medial to the PPS is the oropharynx, which is separated from the palatine tonsil by the superior pharyngeal constrictor. Behind is the prevertebral fascia. On MRI, the PPS is triangular and has high signal intensity. Laterally is the medial pterygoid with medium signal intensity. At this level, the contour of the PPS and its adjacent relationships are very clear. It is thus the best slice to demonstrate the PPS and the parotid, carotid and retropharyngeal spaces.

Transverse section through the body of mandible

At the level of the body of the mandible (Figs. 5, 6), the PPS is only a small space. It is bordered anteriorly by the submandibular gland and laterally by the medial pterygoid and the deep lobe of the parotid gland. Posterior to the PPS is the prevertebral fascia and medial is the oropharynx. On MRI, the PPS is a band of high signal intensity.

Three-dimensional reconstruction of the PPS and its adjacent structures

On a PC, the 3D visualization model of the PPS and its surrounding structures was built. The PPS, mandible, pharynx, the medial and lateral pterygoid muscles, parotid, cervical vessels, styloid process and its muscles, etc., were reconstructed (Figs. 7, 8, 9, 10). All reconstructed structures could be displayed either in a selected

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**Fig. 2** Axial MR image through the foramen magnum. pps, Parapharyngeal space; ℓ, pharyngeal recess; 1, nasopharynx; 2, tensor veli palatini; 3, pharyngeal vein; 4, lateral pterygoid; 5, submandibular nerve and its branch; 6, pterygoid venous plexus; 7, deep lobe of parotid gland; 8, styloid process; 9, levator veli palatini; 10, internal carotid artery; 11, medial pterygoid; 12, ramus of mandible

**Fig. 3** Transverse section through the atlantoaxial joint. ps, Parotid space; pps, parapharyngeal space; ℓ, retromandibular vein; ▲, external carotid artery; 1, palatine tonsil; 2, medial pterygoid; 3, ramus of mandible; 4, masseter; 5, pharyngeal vein; 6, deep cervical lymph node; 7, internal carotid artery; 8, internal jugular vein; 9, dens of axis; 10, digastric; 11, sternocleidomastoid; 12, styloid process and styloid muscles

**Fig. 4** Axial MR image through the atlantoaxial joint. ps, Parotid space; pps, parapharyngeal space; ℓ, retromandibular vein; ▲, external carotid artery; 1, palatine tonsil; 2, medial pterygoid; 3, ramus of mandible; 4, masseter; 5, pharyngeal vein; 6, deep cervical lymph node; 7, internal carotid artery; 8, internal jugular vein; 9, dens of axis; 10, digastric; 11, sternocleidomastoid; 12, styloid process and styloid muscles
group or as a whole. The 3D shape of the PPS is irregular. At the nasopharyngeal region, it is close to the pharyngeal recess, where nasopharyngeal carcinoma often originates from. At the oropharyngeal region, it is adjacent to the palatine tonsil. Anterior to the PPS is the medial pterygoid, medial is the pharynx, lateral is the mandible and posterior are the internal jugular vein and the deep lobe of the parotid gland. The reconstructed structures could be continuously rotated in 3D space at different velocities. Any diameters and angles of the reconstructed structures could be easily measured.

**Discussion**

The PPS is a complex anatomic region due to its 3D shape, its deep situation and its intricate surroundings.
Moreover, it is a key structure in the field of diagnostic imaging in particular, since several masses of different origins can extend into this space. An accurate anatomic knowledge is required for all specialists dealing with this region. In the past, the PPS was studied only by radiological methods [1, 2, 3, 4, 8, 10, 13] or thicker sectional anatomy, which cannot clearly show the tiny structures, or track them because of the layer thickness and loss of tissue in the saw-path. In this study cryosectioning was used to obtain the digital images of the sections, which could more clearly and completely demonstrate the structure of the PPS. In the pre-styloid space, besides the fatty tissue, the pharyngeal vein, ascending pharyngeal artery and their branches and the submandibular nerve can be clearly identified. Thus the Chinese Visible Human male and female data provide detailed thin sectional anatomic materials and a new research method for tiny lesions of the PPS.

The PPS is close to its neighboring structures, separated only by a fascia, so it is difficult to distinguish between deep cervical diseases. However, the location of the disease influences preoperative treatment and the choice of the operative approach [9]. The PPS has a predominantly fatty content that is easily displaced and deformed, and it has high signal intensity on T1-weighted imaging. Thus, the PPS is a better anatomic mark of MRI. In our study, by comparing thin anatomic sections with MRI and building a digitized 3D model of the PPS, the complicated relations of the region could be easily understood. Lateral to the PPS are the masticator space and the deep lobe of the parotid gland. Medial are the nasopharynx and oropharynx covered by the superior pharyngeal constrictor. The carotid space lies posteriorly. The most common PPS lesions may be differentiated from each other by the direction in which the PPS fat or carotid space structures are displaced. For example, masticator space masses displace the fat medially; lesions of the nasopharynx and oropharynx displace the PPS fat anterolaterally; and masses of the carotid space tend to displace the PPS fat anteriorly, but because of the styloid process preventing it, the PPS fat may be not displaced.

The accuracy of a reconstructed image is reliant on the quality of the original two-dimensional data and the slice thickness of the serial sections [6]. In our study cryosectioning was employed in a laboratory at –25 °C to obtain serial sections with no saw-path loss. The thickness of the slice was 0.5 mm and each sectioned image file was 36 MB by using a digital photograph resolution of 6,291,456 (3072×2048) pixels, which proved the 2D data were complete. Then the accuracy and subtlety of the reconstructed images were improved. Four plastic rods were placed parallel to the long axes of the cadaver before it was embedded. On each section the four alignment points could be identified, which were used for aligning the neighboring anatomic images. This allowed the registration of the 3D reconstruction. Surface rendering was used on the PC to reconstruct the PPS and its surrounding structures, which was more convenient and quick to perform and observe. The regional visualization model can provide a 3D solid view to show spatial positions and complicated adjacent relationships. All reconstructed structures could be displayed either in a selected group or as a whole, and could be rotated in 3D space. This is convenient for displaying the shape of a single structure as a whole and observing the anatomic relationships. An interesting structure could be enlarged and the spatial position of the inner structure could be displayed using a transparent technique. On a 3D reconstructed images, the parameters of the PPS region can easily be obtained. This aids the quantitative study of anatomic structures, which provides important data for radiological diagnosis, radiotherapy treatment and surgical planning. It also provides a new and valuable method for anatomic teaching and research of the deep head and neck.
References