Compute Three-Dimensional Reconstruction of Brachial Plexus and its Surrounding Tissues by using Chinese Visible Human (CVH) Data Anatomical foundation for brachial plexus entrapment

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***Abstract*—We selected cervical cross section image from CVH-F1 (Chinese Visible Human – Female, No.1) database. After labeling the relative structures, we made 3D reconstruction of brachial plexus and surrounding tissue by computer reconstruction technique. In cervical cross section image, tissues like vertebrae, disc, spinal dura mater, spinal cord, vertebral artery, nerve root and muscles can be recognized, which ensure the ideal effect of 3-D reconstruction. In conclusion, we can make 3-D reconstruction of brachial plexus through computer technique which may serve for anatomical study of brachial plexus compression. After that we made vertical section on the nerve and calculate the ratio between area of nerve and its gap. In result, it is suggested that the nerve passage for 'root' and 'strand' is comparatively narrower.**

Keywords- external intervertebral foramen, peripheral nerve entrapment, 3-D reconstruction, anatomic research,

I. INTRODUCTION

Periphery nerve entrapment syndrome is one of the frequently occurred surgical diseases. According to pathophysiological research [1], symptoms of most patients were derived from pathological change of surrounding connective tissue of nerve, but not that of nerve itself. Meanwhile, besides thickening of epineurium and perineurium, fibrosis of surrounding tissues was also found in histological examination. Nerve entrapment, such as TOS, cubital tunnel syndrome and carpal tunnel syndrome, usually takes place at certain anatomical site. Therefore related anatomical research of such diseases is of great significance.As most of the former researches of this kind were about autopsy [2-6]and image study [7-9].

II. DATA RESOURCE AND SECTION SELECTION

Primary data of CVH-F1 was collected by Prof. Zhong of China South Medical University. Specimen used was a 19-year-old Chinese female died of alimentary toxicosis. The specimen matched average oriental female well in 20 frequently used parameters (Tab.1). This CVH project was completed in 2002. There are 8556 sections of visible human data, each with a thickness of 0.0079inch, whose storage volume is 149.7GB [10]. Image resolution reaches 6096384(3024*2016) pixels. In the study, the successive sections from C2 to T3, totally 750 layers, were extracted. Then, relating images were observed and identification was made after initial treatment.

I. TECHNIQUE FOR RECONSTRUCTION

A. Dependency structure identification and 2-D labeling

Anatomical structures such as vertebra, spinal cord, vertebral artery, disc, cervical nerve root and etc were observed intensively. The serial No of related picture is from DSCF775 to 1520. 1 every 5 layers was taken from above 750 sections to make reconstruction. In all 750 layers, consecutive slice from DSCF1045 to 1070 stands for cross section of C4-5 intervertebral space; DSCF1071-1110 for C5 vertebrae;DSCF1115-1155 for C5-6 intervertebral space; DSCF1160-1195 for C6 vertebrae; DSCF1200-1235 for C6-7 intervertebral space; DSCF1240-1285 for C7 vertebrae; DSCF1290-1330 for C7-T1 intervertebral space; DSCF1335-1380 for T1 vertebrae; DSCF1385-1425 for T1-2 intervertebral space and DSCF1430-1460 for upper 2/3 of T2 vertebrae. Above layers contains most sections of brachial plexus from its eruption to ending. Therefore 3D reconstruction should display its morphosis and behavior. After being identified all related structures in cross section image, the contour of nerve, bone and surrounding muscle were precisely delineated. Different structure was assigned different gray scale value. Finally, the gap (between regional musculoskeletal structures) of brachial plexus was delineated too. The gap located at the inner margin (between muscle and bone) of surrounding structure. To estimate its area, the trend of discontinued surrounding tissues was traced carefully, which eventually forms an enclosed region.

B. 3-D reconstruction

Computer 3D reconstruction of brachial plexus and its surrounding structure (bone and muscle) is conducted by Image Assisted Diagnosis (IAD Ver1.0) software. Space between sections is prescribed as X*Y*Z=1.2*1.2*1(mm) and the general fusion parameter is set as alpha=0.3-0.6.

Firstly, the contour of body surface of all images was marked and delineated with Photoshop (Adobe Corp). The color insider body was set as white and the background as

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black. Then rudimentary reconstruction was made. The effect was observed to evaluate whether further regulation is required. For reconstruction, body drawing algorithm of Ray Casting was applied to achieve certain perspective effect. The perspective degree can be regulated just by moving the mouse on the model.

II. DISSECTION OF MODEL AND CALCULATION OF THE FRACTION

A. Model designation

The model was rotated and a cutting plane was established. The plexus was cut vertically by the plane, according to its general direction. Several dissections were made at each portion (root, trunk, division and cord) of the nerve respectively. The dissected section was magnified and the chromatic aberration was regulated to achieve optimal contrast effect. The image was saved as JPEG format. Calculate the area, which is the pixel dot of certain gray scale region (in which black stands for nerve and gray for gap), of nerve and gap with Corel Draw software. For nerve goes always inside the gap, the fraction of musculoskeletal gap occupied by the neural elements should be: area of black/ (black + gray).

B. Statistic analysis

All data was expressed as Mean ±Standard Deviation (M ± SD). Interclass difference is compared by one way ANOVA (SAS software Ver8.0). If there is any significant difference, Mutual comparison was made of either 2 groups (Student-Newman-Keuls Test). The standard was set as alpha=0.05. Units

III. USING THE TEMPLATE

Evaluation of the model

A. *Initial localization*

Brachial plexus related sections (fromC4-T2) were analyzed. In all 750 consecutive sections(from DSCF775 to DSCF1520), DSCF1045-1070 is C4-5 intervertebral space; DSCF1071-1110 is C5 vertebral body; DSCF1111-1155 is C5-6 intervertebral space; DSCF1156-1195 is C6 vertebral body; DSCF1196-1235 is C6-7 intervertebral space; DSCF1236-1285 is C7 vertebral body; DSCF1286-1330 is C7-T1 intervertebral space;DSCF1331-1380 is T1 vertebral body DSCF1381-1425 is T1-2 intervertebral space; DSCF1426-1460 is T2 vertebral body.

B. *3D-reconstruction*

Rudimentary contour reconstruction was satisfying.

After reconstruction was finished, C-spine and upper T-spine, brachial plexus and surrounding muscles, can be observed through the body surface. For every kind of structure is reconstructed separately, the image of bone and its surrounding muscle can also be got separately.

Brachial plexus nerve root was sent out from corresponding intervertebral foramen. It then goes externally and inferiorly. At out margin of scalene muscle, C5, 6 converged into upper trunk; C7 migrated into median trunk and C8, T1 formed lower trunk. Afterwards it separated divisions at inner margin of clavicle. And finally it entered axillary fossa, forming into cords at the same time. In its pathway, the nerve was on the whole wrapped in a narrow passage, which was surrounded by bone, muscle and related tendon tissues.

By rotating the model, the structures which we are interested in can be observed at any angle. To achieve better effect, body surface can also be removed.

Separate reconstruction of brachial plexus was made and it was also combined with its surrounding gap. In combined view, we can see there is little gap left within nerve passage.

C. Occupation rate of each stage

The model was rotated to a certain angle and the brachial plexus was cut vertically. Serial sections can be obtained by moving the cutting plane through the axial of the nerve gradually. 9 cross sections of each stage of the nerve was saved. And the fraction of musculoskeletal gap occupied by the neural elements is listed in Tab2. According to statistic result, the whole model is of significance. In which, $F=11.73$, $P<0.05$(one way ANOVA); Result of mutual comparison suggests the stage of root and division have comparatively narrower passage..

TABLE I. 20 BODY PARAMETERS OF VCH-F1 DATABASE*

No.	Items	Value	Range of reference#	Score$
1	height (cm)	155.00	154.40±5.33	5
2	weight (Kg)	46.00	46.22±5.40	5
3	Max. length of head (cm)	17.80	17.83±0.54	5
4	Max. width of head (cm)	15.00	14.52±0.51	5
5	Girth of head (cm)	53.00	52.29±1.31	5
6	Girth of neck (cm)	34.00	32.57±2.15	5
7	Inner distance of eyes (cm)	3.76	3.51±0.36	5
8	outer distance of eyes (cm)	8.77	8.75±0.39	5
9	Width of nose (cm)	3.88	3.59±0.33	5
10	Length of	4.69	5.15±0.42	3

	nose (cm)			
11	Width of mouth (cm)	5.69	4.79±0.36	5
12	Girth of waist (cm)	78.50	76.92±4.23	5
13	Girth of chest (cm)	65.50	67.85±4.83	5
14	Distance between middle fingers (cm)	158.50	154.10±7.08	5
15	Width of shoulder (cm)	38.00	37.47±1.57	5
16	Width of pelvis (cm)	28.50	26.63±1.75	3
17	Width of chest (cm)	27.50	26.57±1.56	5
18	Depth of chest (cm)	16.00	16.91±1.05	5
19	Length of upper limb (cm)	69.00	67.03±2.27	5
20	Length of lower limb (cm)	83.00	82.38±2.87	5
Total				94%

Reference values# were established by Chinese Anatomical Association. If the measuring value within M±SD, the score$ will be 5; If the measuring value within M±2SD, the score will be 3; otherwise, the score will be 0.

*Quoted from Zhong et al. Research Report Of xperimental Database Establishment Of Digitized Virtual Chinese No.1 Female, J First Mil Med Uni 2003;23 (3)

IV. DISCUSSION (OUR FOUNDATION OF THE HYPOTHESIS)

Visible human research is a multi-discipline corporation item, to which many nations of the world endeavored. At the end of 20th century, Spitzer et al [11] at first started the project. Then Park et al [12], Zhang et al [13] and Zhong also participated in it and made their corresponding contributions. Among whom, Zhang had finished first visible oriental human database of man and woman at Oct 2002 and Feb 2003 respectively, following first complete human anatomical database of US.

Visible human database used in the study was completed by Prof. Zhong of the Fourth Military Medical University. In the database, freezing cutting technique made it possible that the interval between successive section was reduced to 0.2mm [14,15]. Though some minute vessels and nerves, which are smaller than cutting distance, may be still hard to discriminate, and nerve also may be torn during cutting, the comparatively greater structure out of cervical extra vertebral foramen is distinctive in corresponding images.

Especially, the brachial plexus can be seen clearly since it goes through the vertebral foramen. Additionally, at various sections we can distinguish such structure as nerve root, trunk, division, median, lateral and posterior cord[16].

Identifying and drawing of 2-D image contour [17-22] is a quite tedious but very important step in 3-D reconstruction [23-25]. CVH database of present study is a set of colored pictures. Referring to the cross-section anatomy of brachial plexus, we can distinguish related structure according to their different color zone. Fulfillment of such work needs identification of various zones in image with special software and professional anatomical knowledge. It's really a kind of hard work. But accurate allocation of the margin of corresponding structure is the foundation of high definition 3-D reconstruction model [26].

In reconstruction, Ray Casting algorithm[27] was applied, which is widely used now. The pixel intensity was calculated according to the sample value of visual line. Therefore, after 3-D reconstruction internal structure can be seen through body surface. Not only the appearance but the spatial location of certain tissue as well may be recognized, which undoubtedly expand the application of the model.

The image diagnosis of brachial plexus is anyway difficult for us. Recent MR technology has raised resolution of nerve display. Diagnosis of tumor, trauma, entrapment and so on can be made and the therapeutic effect can also be evaluated[9]. 3-D reconstruction of plexus [7,8;28]makes direct viewing of its anatomical structure possible, which may identify the compressive position of nerve[29].

As a result, root and division region go through a comparatively narrower passage. Nerve root goes from inter-vertebral foramen to outer margin of scalenus and division goes from middle 1/3 of clavicle to the 1st rib. Former autopsy on entrapment of peripheral nerve disclosed that brachial plexus and vessels were mostly vulnerable in spatium intermusculare and costo-clavicular space. Neurological TOS most frequently occurred in interscalene triangle, secondly in spatium costo-clavicular and subcoracoid space [30]. It is generally accepted that TOS is caused by compression of brachial plexus elements or subclavian vessels in their passage from the cervical area toward the axilla and proximal arm either at the interscalene triangle, the costoclavicular triangle, or the subcoracoid space. Cervical ribs, anomalous muscles, and fibrous bands may further constrict these areas. However, surgical decompression has the definite effect to cure the disease[31].

Nerves and vessels at outlet of thoracic go through interscalene triangle, spatium costo-clavicular and subcoracoid space during pathway to upper limb. Above spaces can compress any tissues inside because of abnormal structure or trauma [4] Nerve compression may be caused by compression, traction or friction. Pratt [5] analyzed vulnerable site of nerve entrapment by observing the anatomy of brachial plexus. Possible sites were photographed during autopsy. Some doctors thought the abnormal fibers in interscalene triangle was one of the reasons for brachial plexus entrapment [32,33]. Crotti et al [34] believed that TOS was the result of post-traumatic pathological change. Prolonged antalgic-contracture and motor neglect may contribute to connective tissue changes and development of micro-adherences. Final result is fibrosis of paraneurium. The pain-immobility-fibrosis loop might be of basic importance in the development of this syndrome.

CONCLUSIONS

In conclusion, we can make 3-D reconstruction of brachial plexus through computer technique which may serve for anatomical study of brachial plexus compression.

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