ORIGINAL ARTICLE

Three dimensional reconstruction of the pancreas based on the virtual Chinese human—female number 1

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Objective: To study the three dimensional (3D) reconstruction and 3D visualisation of the pancreas and create anatomy of the digitalised visual pancreas so as to construct a concrete basis for virtual operation and surgical operation on pancreas.

Methods: The digital imaging data of pancreas, duodenum, common bile duct, arteries, and veins were obtained from the virtual Chinese human—female 1 (VCH-F1). The image data were investigated and 380 images ascertained of pancreas picked up from images numbers 2617 to 2996. Finally, the images from number 2574 to 3017 were adopted to segment and processed using ACDSee and Photoshop so as to reconstruct 3D pancreas digitally. The data of pancreatic surfaces were transformed into Visualization Toolkit (VTK). The GUI program written with VC+ was used to display this VTK file and realise 3D visualisation of the pancreas.

Results: 3D reconstruction and visualisation of the pancreas and the peri-pancreatic structures (the duodenum, the common bile duct, the inferior vena cava, the portal vein vessels, the aorta, the coeliac trunk vessels) was successful. The 3D and visualised pancreas manifested itself with its complete structure as well as its adjacency to other tissues.

Conclusion: The 3D reconstruction and 3D visualisation of the pancreas based on the digital data of VCH-F1 produces a digitally visualised pancreas, which promises a novel method for virtual operation on the pancreas, clinical operation on the pancreas, and anatomy of 3D visualised pancreas.

Surgical operation on the pancreas remains difficult in surgery. Its location, as an external organ deep in the retroperitoneum, its irregular surface, its softness, its close and varied relations with adjacent structures, and its vague boundaries contribute to the difficulty. Under the circumstances, the successful reconstruction of digitalised three dimensional (3D) pancreas, as a key to a virtual operation on pancreas, will help promote the surgical operation on the pancreas to a new stage.¹ For this purpose, we aimed our research at the 3D reconstruction and 3D visualisation of the pancreas based on the data of virtual Chinese human—female number 1 (VCF-F1).

METHODS

The sources of pancreas image data

The data for our research came from the virtual Chinese human—female number 1 started by the Institute of Clinical Anatomy, Southern Medical University.² The cross section image dataset of the pancreas was taken from the iced VCH-F1 slices milled by cryoultramicrotome, each slice 0.2 mm thick and the whole pancreas 7.6 cm long. We probed into the image data and ascertained 380 images of pancreas picked up from images number 2617 to 2996. Finally, we adopted the images from number 2574 to 3017 to segment, capture and reconstruct the 3D structures of pancreas and such key tissues adjacent to it as duodenum, common bile duct, portal vein, and splenic artery.

Segmentation and capturing of the pancreas dataset

The segment covering liver, gall bladder, and pancreas was comprised of the images from number 2574 to 3017, each digital image taken from the cross section slice by miller and containing the digital data of all the tissue. Because of fewer differences in grey values from other tissues, the vagueness of its boundaries, and the infiltration into the important tissues around it, the pancreas could not be made out from the

surrounding structures by only using currently used image identification software. In this case, the original data obtained from VCH-F1 had to be identified, segmented, and labelled manually. Meanwhile, we had to verify the boundaries of pancreas for the sake of image segmentation as the result of its unclear adjacency to the surrounding structures accidentally. Therefore, beginning with the registered pancreas images with distinct boundaries, we checked them one by one to define the boundaries using ACDSee, followed by using such image processing tools as tassel and pen on Photoshop7.0 to describe the boundaries of pancreas to other structures needing reconstruction. After erasing irrelevant image elements, we saved the data to complete the initial segmentation of images. To ensure the actual recovery of the original imaging of pancreas, the image processing had to begin from the images with clear boundaries and then was carried on in the sequential number of labelled images.

The 3D reconstruction

All the images segmented were read in and smoothed by using Gaussian smoothing algorithm. Then, the boundaries were captured by way of isosurface extraction to obtain the data of superficial pancreas, duodenum, common bile duct, arteries, and veins. After completion of capturing superficial data, Gaussian smoothing algorithm was once again adopted to ensure the smoothness of surfaces. Consequently, the data of pancreatic surfaces were transformed into Visualization Toolkit (VTK). We used GUI program written with VC+ to display this VTK file. The final outcome of reconstruction was displayed (figs1 and 2).

RESULTS

Characteristics of pancreas imaging

In our study, 380 images of pancreas were segmented and extracted totally, and saved as BMP documents, each covering 120 KB, totally 45.6 MB as sub-dataset. The

pancreas was characterised by its variety and irregularity in its contour just judging from its one single image, but by the complexity of “fluid” and the mutual infiltration with the peripheral structures judging from the 3D reconstructed pancreas, which clearly showed the impressions rendered by its surrounding structures. The visualised image of pancreas showed the 3D structure in varied directions, highly recovering the 3D interspace conformations of head, neck, body, tail, and uncinate process of pancreas in human body (fig 3).

Characteristics of duodenum imaging

Altogether 396 images of duodenum were segmented and extracted, and saved as BMP documents, each covering 120 KB, totally 47.52 MB as a sub-dataset. The duodenum was characterised with the varied appearance judging from its one single image but with tortuous and mutable appearance judging with its 3D reconstructed image recovering its form from pyloric orifice to the beginning end of jejunum (figs 1 and 2).

Characteristics of common bile duct imaging

In total, 306 images of common bile duct were segmented and extracted and saved as BMP documents, each image covering 120 KB, totally 36.72 MB as a sub-dataset. The segmented images proved the whole common bile duct did not take a round shaped form at its full length and its shape as well as the size of its duct diameter was associated with the peripheral structures. Meanwhile, the reconstructed 3D imaging of the bile duct showed its whole course and run, especially the complicated involvement of its peripheral tissues and structures (figs 4 and 5).

Characteristics of venous system imaging

Altogether, 444 images of venous system were segmented and extracted and saved as BMP format documents, each image covering 120 KB, totally 53.28 MB as a sub-dataset. It was seen that the calibres of key branches of portal venous system remained irregular judging from the segmented images, while its image by 3D reconstruction displayed how the splenic vein and superior mesenteric veins got bound

together and meanwhile showed the changes in spatial structures between portal veins and its peripheral tissues (figs 5 and 6).

Characteristics of arterial system imaging

Altogether, 444 images of arterial system were segmented and extracted and saved as BMP format documents, each image covering 120 KB, totally 53.28 MB as a sub-dataset. The images containing the branches of coeliac trunk and superior mesenteric artery closely linked to pancreas were segmented. The segmented images recovered the varying pattern of arterial prolongation and calibre, while the visualised image by 3D reconstruction displayed distinct structure and the course and their branches, which vivified the close relation between the arteries and their supplied organs (figs 5 and 6).

DISCUSSION

Difficulties in reconstructing pancreas and the relevant countermeasures

Computed tomography (CT) and magnetic resonance imaging (MRI) facilitate the access to obtaining a two dimensional cross sectional image of a human organ. The further integration of two dimensional images by CT and MRI datasets into computer based imaging realised the 3D reconstruction of the liver—the key organ in abdomen.³ Soon the images of sliced cast hepatic duct using CT brought into being the 3D visualised image of hepatic parenchyma and hepatic venous system.⁴ However, the reconstructed 3D image of pancreas through SDD imaging by spiral CT only showed a rough structure of the organ, if used for the analysis and diagnosis of pancreatic carcinoma.⁵ The updated report on 3D reconstruction and visualisation realised 3D reconstruction and display of the pancreas and surrounding vessels, but excluded the duodenum and common bile duct.⁶ As an external organ of peritoneum deep in retroperitoneum, the pancreas typically has irregular surface, soft quality, mutual infiltration with no boundaries to its surrounding structures, and gastrointestinal air and fluids around it, all of which contribute to its vague imaging by CT and MRI and thus the difficulty to reconstruct the pancreatic structure

Figure 1 The reconstructed 3D pancreas and its peripheral structures (anterior view).

Figure 2 The peripheral structures of reconstructed 3D pancreas: The deeper structure of pancreas is seen through when the pellucidity value is set at 0.

solely based on the image data by CT and MRI. That is why the 3D reconstruction and visualisation of pancreas lags behind. PubMed showed the lack of 3D research on the pancreas because of the limited recovery of images⁷ and the absence of reports on systematic reconstruction of pancreatic 3D reconstruction and visualisation.

The two dimensional image dataset from VCH-F1 data has built a solid ground for the 3D reconstruction of pancreas and its peripheral structures.⁸ Every original image from VCH-F1 dataset contains the digitalised data of all the organs and tissues. However, as far as the original image data are concerned, pancreas is not different in grey value, from its

peripheral organs and tissues like duodenum, common bile tract, portal veins, hepatic artery, splenic artery, and superior mesenteric artery so that the current computer software packages are unable to automatically separate and extract the structures of tissues and organs to be reconstructed. Under these circumstances, we first picked up the images with clear structures aided with ACDSee and viewed the sequential images to verify the boundaries between the pancreas and other organs and tissues to be segmented, and then applied Photoshop to separate the images manually. To facilitate both the capturing of images and to protect the natural adjacency between the organs and tissues to be reconstructed, we

Figure 3 The reconstructed 3D image of pancreas (posterior lateral view, superior view) clearly displays its head, neck, body, tail, and uncinate process.

Figure 4 Relations of pancreas and its surrounding structures when the pellucidity value is set at 0 to conceal duodenum (anterior view with a little right handed rotation).

segmented the image of pancreas from duodenum, artery and vein, and common bile duct respectively, immediately after segmentation, capturing, and reconstructions of the images for several times. That is to say, we segmented the pancreas from the duodenum, erased other picture elements, and coloured the duodenum at one image. The procedure was repeated until the pancreas was segmented from duodenum, veins and arteries, and common bile duct. Then the image data of the pancreas and duodenum were captured from the original ones of the pancreas and duodenum and so it was with the image data of arteries, veins, and common bile duct. In this way we completed the segmentation and capturing of image data of pancreas, duodenum, common bile duct, arteries, and veins.

The 3D reconstruction and 3D visualisation of pancreatic imaging

The 3D reconstruction and visualisation must meet the requirements of facilitating understanding of mutual relations between the structures, making it possible to operate in personal computers without difficulty, and showing both the whole structures of pancreas and its peripheral tissues in one place and an arbitrary structure in another.⁹ In calculating the 3D reconstruction, surface rendering is used to generate image data in a small number and resulted in effective display so as to show the superficial details of the 3D subject and facilitate looking into the internal structure of the subject.¹⁰ Volume data contain more abundant and complete data of a subject, thus able to be used to calculate the sections

Figure 5 Relations of common bile duct, artery, and vein when the pancreas and duodenum are concealed (anterior view with right-handed rotation).

Figure 6 The blood vessels around pancreas are clearly shown when the pancreas, duodenum, and common bile duct are concealed.

cut through at any angle. But in our research, we focused more on the contour of the pancreas and the adjacency to its peripheral organs and tissues. Therefore, application of volume rendering would produce large quantities of data and thus cause lower efficiency and what is more it was hard to display the structures of ducts clearly. However, application of surface rendering is able to multiply the operational efficiency of the system and show the contours of superficial and deeper tissues as well as their neighbourhood. Consequently, we used surface rendering to reconstruct the 3D form of pancreas in our research.

The 3D reconstruction and visualisation of pancreas will promote the development of pancreatic surgery

It is known that experienced surgeons cannot guarantee success in duodenectomy and pancreatectomy, which is attributed not only to the features of its own but also to close and diverse relations of the pancreas with duodenum, common bile duct, portal vein, splenic artery and mesenteric artery and vein. On the other hand, the conventional two dimensional images are unable to depict the varied surface of pancreas, let alone the complicated relation of the pancreas in its neighbouring tissues and organs. Furthermore, the pancreas picture derived from anatomical measurements cannot show the reality of the soft pancreas in the human body. In contrast, the 3D reconstructed and visualised image of pancreas in our study is based on the original data from VCH-F1 and therefore characterised by strong sense of stereo, vivid demonstration of irregular surface of pancreas, and actual display of the characteristics of pancreatic head, neck, body, tail, and uncinat process at any angle (fig 3). What is more, the visualised image of pancreas is able to elaborate the structural relations of pancreas with duodenum, common bile duct, artery and portal vein from any angle. In addition, we can look through the mutual structural permeation among pancreas, duodenum, common bile duct, arteries and veins on condition that pellucidit values are set in the process of the data (fig 2); if the pellucidit value is set at 0 for a certain tissue, the structure of the tissue will be concealed and a deeper structure can be seen (figs 5 and 6). It is a great

help for studying clinical surgery and anatomy of pancreas. The cutting of the pancreas at any angle based on our research will promise a good future for developing a software package of virtual operation of the pancreas.

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Conflicts of interest: none declared.

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