Visualization of the omental bursa and its spatial relationships to left subphrenic extraperitoneal spaces by the second Chinese Visible Human model

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Abstract

Purpose In order to overcome the obstacle that detailed spatial relationships of the omental bursa to its related spaces cannot be displayed clearly by thick-slice sectional anatomical imaging and computed tomography, we designed a new approach to three-dimensional (3D) visualization of the omental bursa.

Methods By Amira® software, we employed thin-slice cross-sectional images of the upper abdomen retrieved from second Chinese Visible Human datasets to display the spatial relationships of the omental bursa to its related spaces, especially to the left subphrenic extraperitoneal spaces. Moreover, these spatial relationships were presented on 3D sections reconstructed from second Chinese Visible Human images and computed tomography images.

Results Of importance, the gastric bare area is located among the superior, inferior, and splenic recesses. The appearance of the foramen bursae omenti majoris is the only pathway communicating between the superior and inferior recesses of the omental bursa, and also is the anatomic landmark between the superior and inferior recesses. The splenic recess is surrounded from behind by the splenic bare area and the gastric bare area.

Conclusion As one of the subphrenic spaces, the omental bursa with its related spaces was imaged three-dimensionally using a visualization technique. Familiarity with the anatomic location and spatial relationships of the omental bursa to its related spaces may be beneficial for the differential diagnosis and intervention, improving outcome.

Keywords Visualization · Omental bursa · Left subphrenic extraperitoneal spaces · Splenic bare area · Visible Human Project

Introduction

The omental bursa (OB) is a potential space in the subphrenic area, an irregular space surrounding the caudate lobe of the liver and distributing between the stomach and pancreas on computed tomography (CT) or magnetic resonance images (MRI). Without pathologic fluid collections in the OB in healthy individuals, the OB is normally collapsed. Dehydration and malformation of autopsy specimens exaggerates this collapse. Thus, it is difficult for
medical complications in 2006 [4]. Using 3D visualization, de-
poor regarding the Atlanta definitions of the various local
pancreatitis. Interobserver agreement was found to be
collections influences mortality and morbidity in acute
index score. In addition, treatment of peripancreatic fluid
subphrenic extraperitoneal spaces. According to the ra-
two or more poorly defined collections in or adjacent to
the pancreas were defined as E grade [2]. Due to the fact
that the OB is prone to be involved in acute pancreatitis
[1], whether fluid collections in or around the OB have
been accurately defined would influence the CT severity
index score. In addition, treatment of peripancreatic fluid
collections influences mortality and morbidity in acute
pancreatitis. Interobserver agreement was found to be
poor regarding the Atlanta definitions of the various local
complications in 2006 [4]. Using 3D visualization, de-
tailed anatomic division in each OB recess and spatial
relationships, especially to the left subphrenic extraperi-
toneal spaces, can be clearly displayed. This kind of
anatomic division will be helpful in determining the
correct location of fluid collections in or around the OB in
acute pancreatitis. Subsequently, the CT severity index
score might be as accurate as possible, helping to opti-
mize management.

OB abnormalities included a variety of pathologic enti-
ties: fluid collections due to inflammation, carcinoma,
hemorrhage, and traumatic lesions invading the lesser sac
[5]. There is a rich lymphatic network around the stomach
and pancreas; the lymph nodes within the OB and the
omental foramen are usually involved during lymphatic metastasis from gastric or pancreatic carcinoma. Due to
nonspecific abdominal symptoms and radiologic character-
istics, CT diagnosis of entities involving the OB is difficult
[6]. Except when combined with clinical symptoms and CT
manifestations involving the OB, familiarity with stereo-
coscopic spatial relationships of the OB to its adjacent struc-
tures increases the diagnostic accuracy of OB abnormalities.

We investigated the spatial relationships of each recess
of the OB to its adjacent structures, especially to left
subphrenic extraperitoneal spaces, in order to provide 3D
datasets of each recess of the OB, the gastric bare area, and
the splenic bare area based on the CVH2 datasets. This
information may aid in defining the anatomy of the OB for
medical education purposes and for the diagnosis of OB
abnormalities.

Materials and methods
The study was approved by the Ethics Review Board of the
Chengdu Military General Hospital. The CVH2 datasets
were obtained from voluntary donation [15]. Written con-
sent was obtained from relatives of CVH2 participants. CT
scans of 53 patients with cirrhosis or ovarian carcinoma
were used, although informed consent was waived by the
Institutional Review Board of our Hospital; no identifiable
information (i.e., age and gender) was used.

Three-dimensional reconstruction of the OB and left
subphrenic extraperitoneal spaces based on CVH2

Cross-sectional data of the upper abdomen from the CVH2
CVH2 datasets were from a 22-year-old woman. This
cadaver, which was without organic disease, was do-
nated on a voluntary basis. Successive thin-slice cross-
sectional images of the upper abdomen with a 170-mm
thickness, from the dome of the diaphragm to the lower
pole of the left kidney, were retrieved from the CVH2
datasets for 3D reconstruction. Preliminary CT and MRI
scans were performed on the cadaver to exclude lesions
of the upper abdomen prior to milling. We performed
vascular perfusion with a formaldehyde solution until solution extravasated from the nasal mucosa. Simultaneously, a small amount of ascites formed, and some subspaces in the peritoneal cavity became filled with the solution. The cadaver was placed in a supine position, with the median sagittal plane of the upper abdomen parallel to the body’s long axis. The slice interval was 0.5 mm and the resolution was 6,291,456 (3072 x 2048) pixels. Each Tagged Image File Format (TIFF) picture occupied 36 Mb (approximate pixel size 167 µm), as previously described [15].

Segmentation

With Photoshop CS® (Adobe Systems Incorporated, USA), images were registered through four reserved fiducial rods; the background was removed. In addition, structures including the superior, inferior, and splenic recesses of the OB, the vestibulum bursae omentalis, foramen bursae omenti majoris, gastric bare area, splenic bare area, upper pole of the left retroperitoneal space, left adrenal gland, stomach, and pancreas were outlined with the magnetic lasso tool. Outlines of different structures were filled with distinct colors using the “fill” command. After changing the 16-bit color to 2-bit color, color-filled images were transferred to gray-scale images. The 340 gray-scale images retrieved from the CVH2, including the above structures without background, were imported to Amira 5.2.0® software (TGS Company, USA) and a new stack file with the expanded name “hx” was created. With the “Thresholding” tool provided by Amira 5.2.0®, the above structures were segmented on a threshold basis, and each structure was labeled with a different mask.

Superficial outline reconstruction

After segmentation, the 3D Volume Rendering command was used to reconstruct 3D models of each recess of the OB and the left subphrenic extraperitoneal spaces of CVH2. The surfaces of 3D-reconstructed structures were smoothed with the smooth surface command. The models of superficial outline reconstruction of the OB and its related structures were then displayed.

Multiplanar reconstruction of the upper abdomen

The above 340 serial cross-sectional images of the upper abdomen from the CVH2 dataset were imported to Amira® to obtain the orthoslices of the upper abdomen via multiplanar reconstruction. The orthoslice images were observed in a successive manner, clearly and directly [15].

Anatomy of each recess of the OB and spatial relationships to the left subphrenic extraperitoneal spaces

The anatomical relationships of each recess of the OB to their adjacent structures and the spatial relationships of the OB to the left subphrenic extraperitoneal spaces were explored on consecutive cross-sections and the 3D models of the CVH2. In order to observe certain structures clearly and directly, the 3D models of the OB, the gastric bare area, the stomach, and the pancreas were superimposed on consecutive cross-sections or orthoslice sections.

Omental bursa on CVH2 images versus multislice CT images

Fifty-three patients with cirrhosis or ovarian carcinoma with large peritoneal fluid collections (39 males and 14 females; mean age 37.2 years, range 25–58 years) were recruited to undergo contrast-enhanced 64-slice spiral CT scans (General Healthcare, Milwaukee, WI, USA). Patients met the following inclusion criteria: no history of abdominal disease except for cirrhosis or ovarian carcinoma, and no history of abdominal surgery. Iodine contrast medium was injected (150 ml; 300 mg/ml) through any available superficial vein in the cubital fossa and images were transmitted to Amira® software. Upper abdominal multislice CT coronal or sagittal images were reconstructed using the multiplanar reconstruction technique. The reconstructed thickness of the multiplanar reconstruction was 0.33 mm and the reconstructed interval was 0.33 mm. The spatial relationships among each recess of the OB and their spatial relationships to the gastric bare area, the splenic bare area, the left gastropancreatic fold, the anterior left subhepatic space, the gastrospenic recess, and the splenorenal recess on multislice CT images were studied and compared with those from the CVH2 images. Both superior and inferior recesses being involved by fluid was defined as the communication between these two recesses. If only the superior recess filled with fluid, it meant that these two recesses were obstructed.

Results

Anatomy of the OB

Spatial relationships of the superior recess of the OB to its adjacent structures

On consecutive cross-sections, the superior recess of the OB surrounds the left sides of the caudate lobe of the liver;
namely the caudate lobe of the liver is the right border of the superior recess. The right posterior aspect of the superior recess is the left layer of the coronary ligament; in other words, the superior recess is adjacent to the hepatic bare area in this direction. The hepatogastric ligament lies in its anterior direction; the hepatogastric ligament separates the superior recess from the anterior left subhepatic space. The left of the superior recess is contiguous to the gastric bare area (Fig. 1a). The superior margin of the superior recess attaches to the dome of the left diaphragm; the inferior margin is the vestibulum bursae omentalis (Fig. 1b).

**Communication of the superior and inferior recess of the OB**

The left gastropancreatic fold transmits the left gastric vessels from the posterior abdominal wall to the lesser curvature of the stomach. In the case of the CVH2, the anterior margin of the left gastropancreatic fold, the posterior layer of the hepatogastric ligament, and the gastric bare area are not completely adherent to each other; the area located among them is the foramen bursae omenti majoris (Fig. 2a). This foramen is the only pathway to communicate between the superior and inferior recesses of the OB, and is also the anatomic landmark between the superior and inferior recesses of the OB. The upper part of this foramen is the superior recess and the vestibule, and the lower part contains the inferior and splenic recesses (Fig. 2b).

**Spatial relationships of the inferior recess of the OB to its adjacent structures**

The inferior recess is located among the posterior wall of the stomach, the transverse colon, the transverse mesocolon, and the pancreas. In the case of the CVH2, the upper boundary of the inferior recess overlays the superior margin of the pancreas. Because the jejunum is located cranially to the stomach and pancreas, the lower boundary of the inferior recess is the jejunum and mesentery. The anterior border is the peritoneum, which covers the posterosuperior aspect of the stomach. The posterior border is the peritoneum, on which lies the anterior part of the pancreas (Fig. 3a). The left border is the splenic recess of the OB, the inner margin of the spleen, and the splenic bare area which is composed of the gastroplenic ligament, the splenorenal ligament, and the splenocolic ligament. The right border contains the peritoneal reflections below the beginning of the duodenum and the inner margin of the common hepatic artery (Fig. 3b).

**Spatial relationships of the splenic recess of the OB to its adjacent structures**

In the cross-section of the CVH2, the crescentic splenic recess distributes along the greater curvature of the stomach. Medially, the splenic recess surrounds the greater curvature; the splenic bare area serves as the left boundary. The gastroplenic ligament separates the splenic recess from the gastroplenic recess; the splenorenal ligament separates the splenic recess from the splenorenal recess. The splenic recess is limited to the anterior boundary by the adhering point

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![Fig. 1](image1) **Fig. 1** Visualizing the spatial relationships of the superior recess to its related spaces in the CVH2. The superior recess of the OB is imaged cross-sectionally from the inferior aspect (a) and in 3D from the right (b). 1 Superior recess of the omental bursa, 2 gastric bare area, 3 hepatic bare area, 4 hepatogastric ligament, 5 caudate lobe of the liver, 6 gastric wall, 7 foramen bursae omenti majoris, 8 pancreas, 9 inferior recess of the omental bursa, 10 vestibulum bursae omentalis.
of the gastrosplenic ligament on the greater curvature. In the inferomedian direction, the splenic recess is adjacent to the inferior recess (Fig. 4).

Spatial relationships of the OB to left subphrenic extraperitoneal spaces

Spatial relationship between the OB and gastric bare area

In the cross-section, the gastric bare area lies between the superior and splenic recesses of the omental bursa. The gastric bare area is surrounded by the superior, splenic, and inferior recesses of the omental bursa from the anterointernal, posteroexternal, and inferior directions, respectively, in 3D visualization imaging (Fig. 2b).

Spatial relationship between the OB and splenic bare area

The splenic bare area is adjacent to the splenic recess and inferior recess of the OB. This bare area can be divided into the splenic hilum and splenorenal parts. The splenic hilum part is located in the anterosuperior direction of the inferior
The splenic hilum part surrounds the vast majority of the splenic recess with a semi-arc shape laterally (Fig. 5a). Meanwhile, the splenorenal part distributes in the posterolateral direction of the splenic recess (Fig. 5b).

Spatial relationship between the OB and left retroperitoneal space

The upper pole of left retroperitoneal space lies posteros medial to the splenic recess (Fig. 5b). This upper pole and the splenorenal part of the splenic bare area encircle the latter part of the splenic recess together.

Omental bursa on CVH2 images corresponding with that on multislice CT images

The anatomic location of the OB, its associated vasculature, and its spatial relationships to the adjoining structures on the CVH2 images (Figs. 1a, 4) are well depicted on axial CT images (Fig. 6a, b). The anatomic location of the OB on the CVH2 images is well depicted on coronal and sagittal CT images of patients with ovarian carcinoma created with the multiplanar reconstruction technique (Fig. 6c, d). However, there is no distinct demarcation between the superior recess and the vestibule and there is no distinct boundary between the inferior and splenic recesses; they overlap (Fig. 6a–c) on CT images. The superior and inferior recesses were found to communicate directly with each other in 36 patients (67.9 %, 36/53). The superior recess did not communicate with the inferior recess in 17 patients (32.1 %, 17/53).
Discussion

Although much research concerning the spatial relationships among subphrenic spaces has been performed during gross anatomy, thick-slice sectional anatomy, and CT imaging [8, 9, 11, 17], thin-slice cross-sections retrieved from the Chinese Visible Human datasets have seldom been used. The cross-sections retrieved from Visible Human datasets provide images of a higher resolution than those obtained from CT or MRI scans, and with more detailed anatomic information compared with those from thick-slice sectional anatomy. This type of cross-sectional imaging, therefore, allows for visualization of the spatial relationships of each recess in the OB to its adjacent spaces.

The combination of visualizing 3D models derived from CVH2 datasets with sectional images of the OB and left subphrenic extraperitoneal spaces will contribute to a better understanding of the spatial relationships of each recess of the OB to their adjacent structures, especially to the left subphrenic extraperitoneal spaces, during anatomy instruction (Figs. 1, 2, 3, 4, 5). Furthermore, 3D models of the OB and left subphrenic extraperitoneal spaces can make up for the disadvantage of two-dimensional images, helping medical students to establish a stereoscopic impression of the OB and left subphrenic extraperitoneal spaces (Figs. 2b, 5b).

Fig. 6 Displaying spatial relationships of OB to its adjoining structures on CT images of a woman with ovarian carcinoma. Visualization of the OB on a higher and lower cross-section (a, b), coronal (c), and sagittal (d) images, respectively. 1 Superior recess, 2 inferior recess, 3 splenic recess, 4 left gastropancreatic fold, 5 hepatogastric ligament, 6 anterior left subhepatic space, 7 gastroplenic recess, 8 splenic bare area, 9 pancreas, 10 splenic artery, 11 beginning of the duodenum, 12 common hepatic artery, 13 portal vein, 14 foramen bursae omenti majoris, 15 left gastric artery, 16 gastric bare area, 17 transverse colon, 18 jejunum
Zhao et al. [17] discovered communication between the superior and inferior recesses can be divided into two types: (1) the superior and inferior recesses communicate directly with each other, as in CVH2; (2) the superior recess cannot communicate with the inferior recess. Our results regarding the percentage of communication between these two recesses were consistent with cadaveric data. Prior research asserted that connective tissue associated the anterior margin of the gastropancreatic fold to the posterior layer of the hepatogastric ligament, and that the connective tissue obstructed these two recesses. In our research, we confirmed that the gastric bare area was surrounded by the superior, splenic, and inferior recesses of the OB from the anterointernal, posterolateral, and inferior directions, respectively, in 3D imaging (Fig. 2b). Except for the connective tissue, we believe that the gastric bare area can obstruct these recesses as well. In some individuals with a large gastric bare area, especially if the position of the tip of the triangular gastric bare area is low enough, the gastric bare area will occupy the space of the foramen bursae omenti majoris; the superior recess will not be able to communicate with the inferior recess [14].

Besselink et al. [4] showed that interobserver agreement in the use of the Atlanta classification to categorize peripancreatic fluid collections on CT was poor, even after assessment by experienced abdominal radiologists. We argue that the main reason was that observers did not come to terms with the anatomic allocation of the same fluid collections most of the time. Even then, the anatomic allocation of peripancreatic fluid collections would influence the CT severity index score and further differentiate between moderate and severe acute pancreatitis. In our study, we confirmed that the superior recess overlaps with the vestibulum bursae omentalis, and that the splenic recess is superimposed on the inferior recess on successive cross-sections of CT images (Fig. 6a, b). Therefore, there is no distinct boundary between the superior recess and the vestibule. Similarly, we cannot distinguish the splenic recess from the inferior recess. We suggest that the space above the foramen bursae omenti majoris that surrounds the caudate lobe should be defined as the medial compartment of the OB, while the space below this foramen distributing between the stomach and pancreas should be regarded as the lateral compartment of the OB on CT images. This kind of division corresponds well with the embryogenesis of the OB [12]. If pancreatic fluid involves only the space below the foramen bursae omenti majoris, we consider it to be one location for fluid collections, and count it into the CT severity index score. When pancreatic fluid involves both the medial and lateral compartments of the OB, we consider them as separate locations. Therefore, clinicians and radiologists should compromise with the anatomic allocation of the OB and its adjacent spaces in clinical practice and research. Only in this way can radiologists assess peripancreatic fluid collections with less difficulty, and CT findings will be more compatible with the pathologic progress of acute pancreatitis. Surgeons and gastroenterologists can rely on the radiologist’s CT report of a patient with acute pancreatitis to determine the optimal management.

The left extraperitoneal space lies anterior to the left suprarenal gland and upper pole of the left kidney in Gray’s Anatomy [13]. On the other hand, the left extraperitoneal space is usually named for the gastric bare area clinically [7]. However, as one of spaces that lie outside the peritoneal coverings in left upper quadrant, the splenic bare area participated in the gastric bare area composing the left subphrenic extraperitoneal spaces (Fig. 5). Namely, the left subphrenic extraperitoneal spaces are composed by the gastric bare area and splenic bare area. The OB has intimate spatial relationships to these areas. Familiarity with the relationships of the splenic recess to the splenic bare area and the gastric bare area will be helpful for locating lesions and fluid collections in the left upper quadrant on CT/MRI, especially in distinguishing lesions of the lateral compartment of the OB from the vasculopathy and lymphadenopathy in the splenic hilum, and large tumors in the upper pole of the left retroperitoneal space.

**Conclusion**

In summary, we innovatively used Visible Human Project to present the anatomic location and spatial relationships of the OB to its adjacent structures. The vaguely defined location of the left subphrenic extraperitoneal spaces was clarified by visualization technique. 3D models of the OB may improve the demonstration of the OB anatomy and the detection of the OB pathologic conditions. In practice, the coronal and sagittal reformatted CT/MRI images will help delineate the exact location, origin, or spread pattern of the OB disease, as well as clarify the complex anatomy of the OB.

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**Conflict of interest** The authors declare that they have no conflict of interest.

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