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FULL PAPER

The superior aspect of the perirenal space: could it be depicted by dual-source CT *in vivo* in adults

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Objective: This study aims to observe whether the renal fascias could be effectively shown by dual-source CT (DSCT) and to explore the superior communication of the perirenal space (PS) *in vivo* in adults.

Methods: 275 cases were included in the normal group and 124 cases in the acute pancreatitis group in this study; all images obtained by DSCT were observed; the superior adherence of the renal fascias and the pattern of superior communication of the PS were judged; and the consistency between the two groups was compared.

Results: The superior adherence of the renal fascias was reliably displayed in 57.8% of the normal group and 69.4% of the acute pancreatitis group, the anterior renal fascia (ARF) did not fuse with the posterior renal fascia superiorly. The left ARF fused with the posterior parietal peritoneum in

57.9% of the normal group and 45.3% of the pancreatitis group, where the left PS communicated with the sub-diaphragmatic retroperitoneal space (SDRS). The left ARF fused with the peritoneum laterally and simultaneously with the inferior phrenic fascia medially in 42.1% and 54.7% of each group, respectively, where the left PS was open towards the SDRS laterally but sealed off from the SDRS medially. The right ARF fused with the peritoneum in all cases; and the right PS was open towards the bare area of the liver.

Conclusion: To some extent, DSCT can display renal fascia and its superior adherence and reflect the superior communication of the PS.

Advances in knowledge: This study was conducted *in vivo* in adults by high-resolution DSCT, and more samples could be provided.

Retroperitoneal space is a three-dimensional space, ranging from the diaphragm to the pelvic extraperitoneal space longitudinally, between the post-parietal peritoneum and the transverse fascia of the posterior abdominal wall, with its lateral side extending to the extraperitoneal fat. The kidneys are located in the retroperitoneal space and embedded by fascia. Retroperitoneal spaces are complicated, the inside fascias divide the retroperitoneal space into different spaces. Although many researchers have studied through different methods the superior communications among these spaces there are still controversies; some scholars believed that the perirenal space (PS) opens upwards,¹⁻⁷ while others supported that the PS is upwardly closed.⁸⁻¹¹ Until now, most anatomical and radiological studies of the superior adherence of the renal fascia in retroperitoneal space employed the sectional anatomy on cadavers, the contrast medium injection of the cadaveric retroperitoneal space or the imaging studies based on the retroperitoneal effusion, but there were some deficiencies in such studies. In order to avoid anatomical distortion by these methods, we aimed to carry out research *in vivo* on adults to explore whether the renal fascias and the superior communication of the PS could be

shown by high-resolution dual-source CT (DSCT) and post-processing technique, which could offer more samples at the same time. We hope that it could be helpful for anatomical positioning of diseases and analysis of their spread easily and visually, as well as the choice of treatment.

METHODS AND MATERIALS

Cases

Normal group

636 contiguous patients suspected of renal or adrenal diseases underwent contrast-enhancing thin-slice DSCT and were retrospectively screened in West China hospital (Chengdu, China) from October 2012 to March 2013.

Inclusion criteria: retroperitoneal anatomical structures were normal, they were not disturbed by patients' diseases, and renal fascia thickness was <2 mm.

Exclusion criteria: (1) less than 18 years old; (2) retroperitoneal or peritoneal lesions (e.g. infection, fluid, tumour) affecting the retroperitoneal structure; (3) thickening of renal fascia (renal fascia thickness >2 mm) caused by any

reasons; (4) poor image quality resulting in failure to evaluate the attaching position of the renal fascia.

275 cases met the above criteria, in which 116 (42.2%) cases were excluded because the superior adherence of the renal fascia could not be confirmed by dynamic images. The other 159 (57.8%) cases, including 96 males and 63 females, were enrolled, with their ages ranging from 21 to 86 years (average age of 52.3 years).

Acute pancreatitis group

182 cases of contiguous patients with acute pancreatitis were retrospectively screened in West China hospital from October 2012 to March 2013.

Inclusion criteria: all cases had typical clinical manifestation of initial acute pancreatitis, serum amylase or lipase exceed more than three times the upper limit of the normal value. No obvious retroperitoneal effusion covered up the superior attaching position of the renal fascia, and bilateral renal fascias were thickened (thickness >2 mm) owing to inflammation.

Exclusion criteria: (1) less than 18 years old; (2) retroperitoneal structures destroyed by pancreatitis or covered by effusion; (3) unilateral thickening of renal fascia; (4) renal fascia thickness <2 mm; (5) unable to evaluate the attaching position of the renal fascia owing to poor image quality.

124 cases met the above criteria, in which 86 (69.4%) cases were enrolled, including 55 males and 31 females, ages ranging from 24 to 85 years (average age of 53.9 years). The other 38 (30.6%) cases were excluded because the superior adherence of the renal fascia could not be confirmed.

Equipment and scanning methods

CT scanning

CT enhancement scan was conducted by using Siemens DSCT (Siemens Somatom® Definition Flash; Siemens Healthcare Sector, Forchheim, Germany), and all patients were scanned in a craniocaudal direction from the top of the diaphragm to the iliac crest during inspiratory breath-hold. Forearm bolus injection with organic iodine contrast agent was conducted, the contrast dose was 1.5–2.0 ml kg⁻¹ of body weight with the injection rate of 3 ml s⁻¹, and scan delay time was 60 s at the portal venous phase.

Scanning parameter

Scanning parameters were voltage of 120 kV, current of 200–220 mA, collimator of 32 × 0.6 mm, pitch of 0.7, slice thickness of 0.5–1.0 mm, reconstruction matrix of 512 × 512, window width of 300–400 Hu and window level of 40–60 Hu.

Image reconstruction

Image post-processing was conducted at the Siemens image workstation. Multiplane reconstruction method was employed to reconstruct sagittal images that were perpendicular to renal fascia. Slice thickness was 0.5–1.0 mm for image reconstruction. Reconstruction plane extended outwards from the vertebral column to the lateral abdominal wall.

Figure 1. The diagram shows the left anterior renal fascia fused with the parietal peritoneum (arrows) on sagittal images, including splenorenal ligament at the lateral part and omental sac behind the stomach at the medial part. The left posterior renal fascia fused with the inferior phrenic fascia and psoas fascia (arrowheads). The left perirenal space communicated with the subdiaphragmatic retroperitoneal space. K, kidney; Sp, spleen; St, stomach.

Assessment

One professor and one attending doctor of abdominal speciality observed the image at the workstation, combined with the axial and sagittal images, and the superior communication of the PS was determined. The observers were free to use post-processing and windowing options, and consensus was reached through discussion in case of any discrepancy.

Statistical analysis

A χ^2 test was used for the evaluation of the obtained data. Statistical analysis was conducted to assess if there was statistical difference of the superior communication of the left PS and subdiaphragmatic retroperitoneal space (SDRS) between the normal group and the acute pancreatitis group. Statistical significance was set at $p < 0.05$.

Ethical standards

This study complies with the current laws of our country.

RESULTS

Superior adherence of renal fascia

Left side

The left anterior renal fascia (ARF) fused with the posterior parietal peritoneum, including the splenorenal ligament and omental sac behind the stomach, at the lateral and medial parts, respectively in 92 of 159 cases (57.9%) in the normal group (Figures 1 and 2a) and 39 of 86 cases (45.3%) in the pancreatitis group (Figures 1 and 2b).

Figure 2. Contrast CT image shows the left anterior renal fascia fused with the peritoneum of splenorenal ligament and omental bursa at the lateral and medial part, respectively (arrows), on sagittal images perpendicular to renal fascia. The left perirenal space communicated with the subdiaphragmatic retroperitoneal space: (a) in a normal case and (b) in a pancreatitis case. K, kidney; Sp, spleen; St, stomach.

The lateral part of the left ARF fused with the splenorenal ligament, but the medial part fused with the inferior phrenic fascia in 67 of 159 cases (42.1%) in the normal group (Figures 3 and 4a) and 47 of 86 cases (54.7%) in the pancreatitis group (Figures 3 and 4b).

The left ARF terminated above the level of the left adrenal gland. In general, the trend of the ARF was high in the medial side and low in the lateral side.

The left posterior renal fascia (PRF) fused with the psoas fascia and inferior phrenic fascia in both groups (Figures 1, 3 and 5), and the trend was high in the lateral side and low in the medial side.

Right side

The right ARF fused with the posterior parietal peritoneum of the hepatorenal ligament in both groups (Figures 6 and 7). Superiorly, the right ARF terminated approximately at the level of mid-height of the right kidney, and the trend was high in the medial side and low in the lateral side in general.

The right PRF fused with the psoas fascia and inferior phrenic fascia in both groups (Figures 6 and 7), and the trend was high in the lateral side and low in the medial side.

The ARF of each side was not completely continuous in all cases of the normal group on the images of DSCT.

Figure 3. Diagram showing the left anterior renal fascia fused superiorly with the inferior phrenic fascia medially (arrow) and the left posterior renal fascia fused with the psoas fascia medially (arrowhead). The medial part of perirenal space could not connect with the subdiaphragmatic retroperitoneal space. K, kidney; St, stomach.

Superior communication of the perirenal space

The left PS was open towards the SDRS in 57.9% (92/159) cases of the normal group (Figures 1 and 2a) and 45.3% (39/86) cases of the pancreatitis group (Figures 1 and 2b). The lateral side of the PS communicated with the SDRS, while the medial part of the PS was sealed from the SDRS in 42.1% (67/159) cases of the normal group (Figures 3 and 4a) and 54.7% (47/86) cases of the pancreatitis group (Figures 3 and 4b).

The difference was not statistically significant for the superior communication of the left PS and SDRS between the normal group and the acute pancreatitis group (Table 1; $\chi^2 = 3.51$; $p > 0.05$).

The right PS communicated with the bare area of the liver superiorly (Figures 6 and 7) in all cases of the normal group and the pancreatitis group.

DISCUSSION

For division of retroperitoneal space, the generally accepted viewpoint was proposed by Meyers¹² in the late 1960s and early 1970s on the basis of Congdon's anatomical studies,¹³ which is, the retroperitoneal space was classified by the renal fascia as follows: (1) anterior pararenal space, located among the posterior parietal peritoneum, ARF and lateroconal fascia; (2) PS, located between the ARF and PRF, with a shape like an inverted cone; (3) posterior pararenal space, located among the transverse fascia, PRF and lateroconal fascia. Retroperitoneal spaces are complicated, the inside fascias divide the retroperitoneal space into different spaces. Controversies are still present about the relationship between these fascias and spaces.

As early as the 1940s, some scholars found through autopsy that the ARF terminated at the level where the transverse mesocolon was attached to the posterior parietal peritoneum, so they reached the conclusion that the PS was open upwards and communicated with the SDRS. While Meyers⁸ thought that the ARF and PRF fused above the level of adrenal gland and then extended up to the inferior phrenic fascia, the PS was closed superiorly. This viewpoint was supported by some scholars, including Raptopoulos et al.¹⁰ Wolfram-Gabel et al.¹¹ found by foetal histological study that the anterior and posterior layers of the renal fascia fused at the upper pole of the retroperitoneal space to become continuous with the inferior fascia of the diaphragm, which supported that the PS was upwardly closed.

Lim et al⁵ found that the ARF fused with the posterior parietal peritoneum, the PRF fused with the psoas fascia or the inferior phrenic fascia, and the ARF and PRF did not fuse mutually above the kidney. Matsubara et al⁶ identified through early stage foetal study that the ARF extended along the peritoneum and often fused with the latter. Lately, Meyers et al¹⁴ also agreed that the right PS communicated with the bare area of the liver. In China, Jiang et al² also obtained the same viewpoint as Lim et al⁵ through autopsy study. Jiang et al² found that the right ARF fused with the posterior parietal peritoneum at the hepatorenal ligament on autopsy, the left ARF fused with the posterior parietal peritoneum on the slightly upper plane of the pancreas, the lateral part fused with the peritoneum at the splenorenal ligament and the medial part fused with the posterior parietal peritoneum of omental sac, the ARF also attached to the pancreatic capsule at the posterior border of the pancreas. The PRF on the left and right sides extended superiorly to fuse with the psoas fascia and inferior phrenic fascia, which constituted the posterior border of the PS.

For the two groups in our study, we found that the ARF was not completely continuous in all cases of the normal group, especially near the posterior border of the pancreas. This maybe attributed to less retroperitoneal fat blurring the display of the fascia, or the ARF partially attaching to the pancreatic capsule. We could not exclude if the fascia itself was fenestrated. Medially, the ARF disappeared gradually near the midline above

Figure 4. Contrast CT images showing the left anterior renal fascia fused with the peritoneum of splenorenal ligament laterally (arrows) and the inferior phrenic fascia medially (arrowheads). The medial part of the perirenal space could not connect with the subdiaphragmatic retroperitoneal space: (a) in a normal case and (b) in a pancreatitis case. K kidney; Sp, spleen; St, stomach.

the level of the superior mesenteric artery in both normal and pancreatitis groups. It is possible that the ARF blended with the tissues in the vicinity of the midline. We found that the positions of superior adherence and distribution of the ARF and PRF were similar to the study made by Jiang et al.² In all cases, the right ARF and PRF did not fuse above the kidney, indicating that the right PS extended up into the bare area of the liver. In some cases, the left ARF fused with the posterior parietal peritoneum upwardly, including the splenorenal ligament and the omental sac, indicating that the left PS opened upwards and connected with the left SDRS, which is consistent with the viewpoints of Lim et al.⁵ and Jiang et al.² However, we still found that, in approximately 42.1% of the left ARF in the normal group and 54.7% in the pancreatitis group, the lateral part of the left ARF fused with the splenorenal ligament and the medial part fused with the inferior phrenic fascia, rather than fusion with the peritoneum of the omental sac, enabling the lateral part of the left PS to connect with the SDRS while

the medial part was sealed off. This was more obvious in the pancreatitis group than in the normal group, and we thought that the reason for this difference between the two groups was that the medial part of the left ARF near the midline of subdiaphragmatic areas was relatively difficult to see in the normal group owing to fewer fat tissues in this area, which could blur the fascia and affect the judgment about the superior attachment position of the ARF, whereas ARF in cases with pancreatitis was easier to observe owing to its thickening caused by inflammation.

We thought that the anatomical details of renal fascia could be better revealed by fascial thickening in some conditions such as acute pancreatitis, and acute pancreatitis was a common disease in our hospital. Therefore, we chose the pancreatitis cases as the control group and compared the normal group with the pancreatitis group to judge if the normal cases could display the superior communication of the PS accurately. The results

Figure 5. Contrast CT images showing the left posterior renal fascia fused with the psoas or inferior phrenic fascia (arrows): (a) in a normal case and (b) in a pancreatitis case. K, kidney; Sp, spleen; St, stomach.

showed that the difference of the superior communication of the left PS between the two groups was not statistically significant, and the right PS communicated with the bare area of the liver in all cases of these two groups, which meant the superior adherence of the renal fascias could be displayed under normal circumstances by DSCT.

This study employed high-resolution DSCT that is equipped with two X-ray tubes and two corresponding detectors; the scanning speed was improved and 0.4-mm cylinders could be resolved at all heart rates,¹⁵ which means it has higher spatial resolution and temporal resolution than that of the single-source CT, therefore, the diagnostic image quality is theoretically improved.¹⁶ The display rate of the renal fascia was improved, and our study *in vivo* could avoid the disadvantage of autopsy or perfusion, which may affect the display of the normal renal fascia. Meanwhile, more samples could be provided. Understanding of such anatomical characteristics is beneficial for location of diseases such as retroperitoneal infection, tumour, trauma etc. It has important guiding significance for

Figure 6. Diagram showing the right anterior renal fascia fused with the peritoneum of the hepatorenal ligament (arrow) and the right posterior renal fascia fused with inferior phrenic fascia (arrowhead). The right perirenal space communicated with the bare area of the liver. K, kidney; Li, liver.

determining the distribution patterns and diffusion paths of retroperitoneal lesions, also for choosing of therapeutic methods.

Figure 7. Contrast CT images showing the right anterior renal fascia fused with the peritoneum of the hepatorenal ligament (arrows) and the right posterior renal fascia fused with the psoas or inferior phrenic fascia (arrowheads) on sagittal images. The right perirenal space communicated with the bare area of the liver: (a) in a normal case and (b) in a pancreatitis case. K, kidney; Li, liver.

Table 1. The superior communication of the left perirenal space (PS) with the subdiaphragmatic retroperitoneal space (SDRS) in different groups

Groups	The left PS open towards the SDRS	The lateral part of the PS open towards the SDRS while the medial part sealed off from the SDRS	Total
Normal group	92	67	159
Pancreatitis group	39	47	86

$\chi^2 = 3.51$; $p > 0.05$.

Limitations of this study

Inadequacies of this study include:

- (1). The results of the present study design still could not explain some clinical phenomena such as the flow and distribution of inflammatory fluid in different retroperitoneal spaces. Some scholars^{9,17,18} put forward the theory of “interfascial plane” to explain the spreading pathways of various pathological entities in different spaces, but basal and clinical research evidence about this theory is still insufficient.
- (2). For the normal group, the selected subjects must have proper retroperitoneal fat to better display the renal fascia and its superior attaching point. 42.2% (116/275) cases were excluded from the normal group owing to the inability to display the superior attachment positions of the renal fascia, which was attributed to less retroperitoneal fat.
- (3). For the pancreatitis group, adhesion caused by inflammation may affect the judgment about the correlation of the retroperitoneal space, and inflammatory infiltration within the fatty tissue could imitate the perirenal fascias. Such inadequacies have an impact on the observation of the extension and adherence of renal fascias. As a result, observers must trace the retroperitoneal space dynamically and carefully to identify the renal

fascia. Based on these reasons, 30.6% (38/124) cases were excluded in the pancreatitis group because the superior adherence of the renal fascia could not be confirmed.

- (4). We could not negate that there may be some other variations of the superior adherence in those excluded cases of both groups. Along with continuous development of imaging technology, these issues and disadvantages need to be further explored and resolved.

CONCLUSIONS

The current CT technology is not fully effective in displaying the superior attachment of the renal fascia *in vivo*, but it still could display the renal fascia and the superior communication of the PS under certain conditions. Through our study, we found that the right PS communicated with the bare area of the liver superiorly in all cases of the two groups, and the left PS communicated with the SDRS in some cases, which conforms to some other scholars' research. We also found that in some cases, the lateral part of the PS was open towards the SDRS, while the medial part was sealed off from the SDRS.

To a certain extent, DSCT could display the renal fascia and the superior communication of the PS.

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