Detection of retroaortic left renal vein and circumaortic left renal vein by PET/CT images to avoid misdiagnosis and support possible surgical procedures

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Abstract

Objective: We aimed to identify retroaortic left renal vein (RLRV) and circumaortic left renal vein (CLRV) by using positron emission tomography/computed tomography (PET/CT) images, to obtain their percentages and to evaluate the effect of gender on their frequencies. **Subjects and Methods:** Plain CT and fluorine-18-2-fluoro-2-deoxy-D-glucose PET/CT images of 222 consecutive patients who underwent oncological PET/CT imaging were used to detect RLRV and CLRV. The numbers and percentages of total left renal vein (LRV) variations, RLRV and CLRV were obtained. Fisher's exact test was used to determine the relation between the LRV variations and gender. **Results:** In the whole group (n=222), the percentages and the numbers of total LRV variations, RLRV and CLRV were 5.85% (n=13), 2.70% (n=6) and 3.15% (n=7), respectively. In male population (n=116), the percentages and the numbers of total LRV variations, RLRV, and CLRV were 6.03% (n=7), 2.58% (n=3) and 3.45% (n=4), respectively. In female population (n=106), the percentages and the numbers of total LRV variations, RLRV, and CLRV were 5.66% (n=6), 2.83% (n=3) and 2.83% (n=3), respectively. The percentages of RLRV and CLRV were found to be independent of gender (P=1.000). **Conclusion:** PET/CT is a useful imaging modality in detecting RLRV and CLRV. The relationship of gender with RLRV or CLRV was not statistically significant.

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Introduction

Normally a single left renal vein (LRV) crosses anterior to the abdominal aorta before draining into inferior vana cava (IVC) in the majority of cases. However there are also anatomical variations of LRV, the most common ones being a retroaortic left renal vein (RLRV) and a circumaortic left renal vein (CLRV) [1, 2]. A RLRV is a single LRV which drains into IVC after a retroaortic course. A CLRV is a left renal vein complex composed of two veins with preaortic and retroaortic courses which drain into the IVC after forming a venous collar around the abdominal aorta. In various studies, a wide range of percentages of RLRV and CLRV were reported as 0.5%-7.4% and 0.3%-6.3%, respectively [1-11].

Detection of LRV variations is clinically important for both surgical [12, 13] and diagnostic [14] reasons. Potential serious complications can be avoided by identification of these veins variations in retroperitoneal surgery [3, 13]. Careful evaluation of CT images is necessary to differentiate LRV variations from retroperitoneal lymphadenopathy [14]. Helical CT [2] and multidetector CT [7, 8] are efficient, fast and reliable imaging modalities in identification of LRV variations. Besides helical CT and multidetector CT, positron emission tomography/computed tomography (PET/CT) has also been used to demonstrate RLRV and CLRV [15] but to our knowledge, the present study is the first to report the percentages of RLRV and CLRV found by using PET/CT images. We aimed to identify the most common LRV variations (RLRV and CLRV), to obtain their percentages and to evaluate the effect of gender on their frequencies, by using PET/CT images which were readily obtained in our daily practice of oncological imaging.

Data analysis

Study population

Between June 2014 and November 2015, PET/CT images of 225 consecutive patients who underwent routine oncological PET/CT examinations for imaging (initial diagnosis of a malignancy, staging of a known cancer, assessing tumour response to therapy etc.) were evaluated in this prospective study. Three of them, all male, were excluded. One of the excluded patients had pelvic ectopic left kidney, one had left sided IVC (transposition of IVC) and one patient was very cachectic, which made the evaluation of LRV impossible. Our study group (n=222) consisted of 116 males and 106 females. Their mean age was 56.53±14.1 years (range, 16-84 years). All procedures were performed according to the World Medical Association Declaration of Helsinki (revised in 2000, Edinburgh) [16]. All patients or their close relatives were informed about the PET/CT examination procedures, and their informed consent was obtained. Since all patients were referred with oncological indications, patients with non-cancerous indications for a PET/CT study were not included.

PET/CT protocol and image analysis

Both abdominal plain CT images and radiolabeled ^{18}F-FDG abdominal PET/CT images were used to detect the two main LRV variations, RLRV and CLRV. Since our aim was to use only the routine PET/CT images which were readily obtained for oncological imaging, we did not get any additional CT images for more detailed or further visualisation of LRV variations, in order to avoid any unnecessary radiation exposure. The patients fasted for at least 6 hours before the study, with a plasma glucose level below 150-200mg/dL was obtained at the time of ^{18}F-FDG administration (mean plasma glucose level, 100mg/dL). The ^{18}F-FDG was injected intravenously in a dose of 259-399.6MBq. Whole-body emission scanning (7-14 bed positions; acquisition time, 3min/bed position) was performed 50 minutes after ^{18}F-FDG administration, the patient lying in supine position. In the majority (n=213) of the patients, scanning was performed from head to the proximal thigh. The rest of the patients (n=9) were scanned from head to feet. Hybrid imaging was performed using a Discovery 610 (General Electric Medical Systems, LLC, Waukesha, WI, USA) PET/CT scanner. Computed tomography images were obtained during breath holding using the following parameters: detector row configuration, 16x1.25mm; tube voltage, 120-140kVp; maximum tube current, 220mA; beam collimation, 20.0mm; table speed, 27.5mm/rotation; pitch, 1.375:1; helical thickness, 3.75mm and 512x512 matrix. Prior to PET/CT examination, a solution of iodinated nonionic contrast material was given orally for bowel opacification. We did not administer intravenous by iodinated contrast media. Images from PET/CT for each scan were evaluated by a Board-certified nuclear medicine specialist with 13 years experience and by a Board-certified radiologist with 14 years experience, in consensus, reporting together on the same setting. Anatomic tracking of LRV through its course was performed by following it from renal hilus to IVC uninterruptedly by using consecutive images. A single LRV which drained into IVC after a preaortic course was accepted as normal LRV (Figure 1).

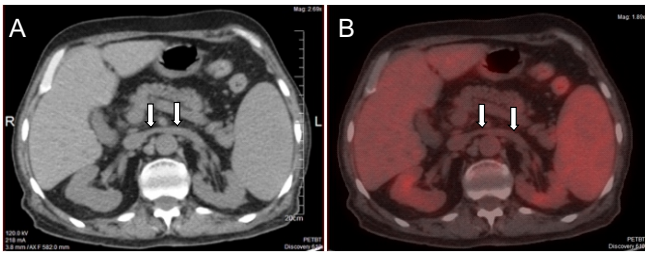

Figure 1. Axial plain CT (A) and fused PET/CT (B) images of normal (single, preaortic) LRV (white arrows).

A single LRV which drained into IVC after a retroaortic course was accepted as RLRV. Double left renal veins which drained into IVC after forming a venous collar around abdominal aorta with preaortic and retroaortic courses, were accepted as CLRV. Accumulation of ^{18}F-FDG in left renal pelvis and in proximal left ureter provided a contrast effect to distinguish these structures from adjacent LRV. In order to differentiate the LRV or its variations from the adjacent left renal artery (LRA) and from any detectable accessory LRA, these arteries were followed uninterruptedly from their origins-most commonly from the left lateral aspect of the abdominal aorta to the left kidney by using consecutive images. In patients with atherosclerosis, hyperdense atheromatous calcifications on plain CT images were used as pathologic landmarks to detect the origin of LRA.

Statistical analysis

The percentages and the numbers of total LRV variations, RLRV and CLRV were obtained. Fisher's exact test was used to determine the relation between the LRV variations (RLRV, CLRV) and gender. P values<0.05 were considered as statistically significant. All analyses were done with SPSS software (version 16.0; SPSS Inc; Chicago, IL, USA).

Results

Regarding the whole study group (n=222), the percentages and the numbers of total LRV variations, RLRV (Figure 2) and CLRV (Figure 3) were 5.85% (n=13), 2.70% (n=6) and 3.15% (n=7), respectively. In the male population (52.25%, n=116) , the percentages and the numbers of total LRV variations, RLRV, and CLRV were 6.03% (n=7), 2.58% (n=3) and 3.45% (n=4), respectively. In female population (47.75%, n=106), the percentages and the numbers of total LRV variations, RLRV, and CLRV were 5.66% (n=6), 2.83% (n=3) and 2.83% (n=3), respectively. The percentages of both RLRV and CLRV were found to be independent of gender (P=1.000). Descriptive and percentage information about the patients is given in Table 1. Distribution of LRV variations is given in Table 2.

Discussion

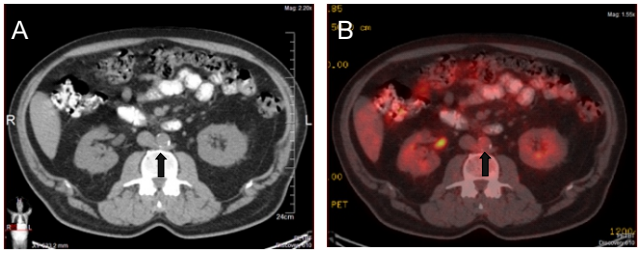

Figure 2. Axial plain CT (A) and fused PET/CT (B) images of RLRV (black arrows). Axial plain CT (a) and fused PET/CT (b) images of RLRV (black arrows).

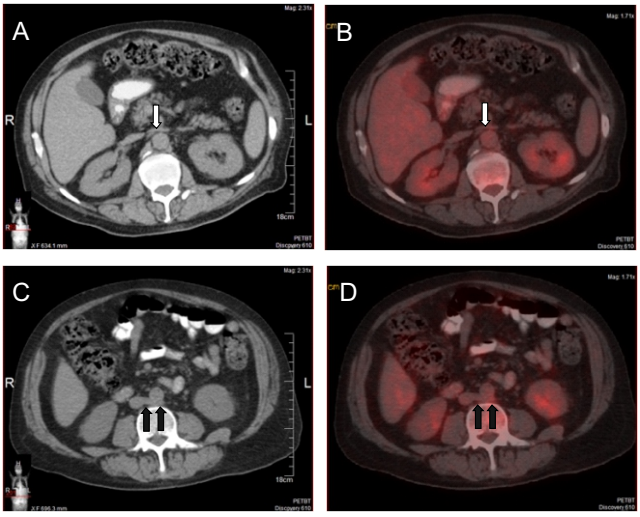

Figure 3. Axial plain CT (A, C) and fused PET/CT (B, D) images of CLRV (white arrows: preaortic component, black arrows: retroaortic component).

Table 1. *Descriptive and percentage information about the patients*

Gender	Females	Males
Number	106	116
Percentage (%)	47.75%	52.25%
Age (Mean±Standard Deviation)	53.75±13.68 years	59.08±14.09 years

Table 2. *Distribution of LRV variations*

	Females	Males	P values*
Total LRV	5.66%	6.03%	1.000
RLRV	2.83%	2.58%	1.000
CLRV	2.83%	3.45%	1.000

*P values < 0.05 were considered as statistically significant.

Subcardinal veins which mainly drain the kidneys, develop during the fifth to seventh week of the embryological period and LRV forms as a result of the anastomosis between the subcardinal veins [17]. However, during the embryological period, variations of LRV can occur due to the unusual persistence or regression of these anastomoses: a CLRV results from the persistence of both an intersubcardinal anastomosis anterior to the aorta (dorsal limb of the embryonic left renal vein) and an intersupracardinal anastomosis posterior to the aorta (dorsal arch of the renal collar), whereas a RLRV results from the persistence of the posterior intersupracardinal anastomosis (dorsal arch of the renal collar) with regression of the ventral arch of intersubcardinal anastomosis [18, 19].

In the past, interventional and more invasive imaging methods such as renal venography were used to detect LRV variations [3]. However non-invasive or relatively less invasive, non-interventional modalities are more often used over the last few decades [1, 2, 4-10, 20-22]. Color Doppler ultrasonography can be used to evaluate LRV variations [5, 21], but it is rather operator-dependent, time consuming and has limited value in obese patients [10]. Variations of LRV can also be demonstrated by using magnetic resonance imaging (MRI) without exposing the patient to ionizing radiation and without administration of any intravenous contrast media [1]. However, MRI is more costly and time consuming as compared to helical or multislice CT [2]. Intravenous contrast-enhanced CT examinations with helical or multislice devices were reported to be the preferred methods in identification of LRV variations because of being less costly, less time consuming, efficient, more practical and with high patients' compliance [2]. Nevertheless, ionizing radiation and potential nephrotoxicity of contrast media still remain to be the main unfavourable features of contrast-enhanced CT examinations [23, 24]. In our PET/CT studies we do not administer intravenous contrast media. Although ionizing radiation originating from intravenously administered ^{18}F-FDG and the CT device is the major disadvantage of PET/CT, its use is inevitable in current and common oncological imaging practice. To identify LRV variations in our original study, we intended to evaluate the images of the patients who already underwent PET/CT imaging for oncological purposes, without performing any further imaging study which would increase the radiation burden for the patient.

By using PET/CT both morphological and functional data can be obtained in oncological imaging. However, one should be aware of some diagnostic pitfalls in PET/CT images. A thrombosed RLRV can mimic a retroperitoneal neoplasm [25] so if one is familiar with LRV variations may avoid misdiagnosis. Furthermore, in patients with solid tumours, evaluation of LRV on PET/CT images has clinical importance in diagnosing a possible tumour thrombus in this vein [26]. Coincidental pathologies such as nutcracker syndrome can also be detected on PET/CT images [27]. Besides these pathological findings, normal anatomic variations of LRV can also be identified by PET/CT in cancer patients [15, 28]. The left paraaortic region is a common location of normal vascular and other anatomic structures which may mimic tumours on CT images [29]. While evaluat-

ing these locations with PET/CT, the LRV variations should be taken into consideration to avoid misdiagnosis. Furthermore, these variations should be reported because may be useful for treatment planning, such as to decrease the number of improperly positioned IVC filters in treating cancer patients [28]. Being informed about the LRV variations before performing retroperitoneal surgery is very important for a surgeon to avoid any injury to these structures, to prevent subsequent hemorrhage and possible death [9, 13, 30]. The patients who undergo PET/CT for oncological imaging are candidates for many of the above mentioned risky interventional procedures. In our study, pathological ^{18}F-FDG uptake of metastatic retroperitoneal lymph nodes helped us to distinguish LRV and its variations which was surgically important for the patients who would undergo retroperitoneal lymph node/mass biopsy or surgery. We consider that the results we obtained from our study will emphasize the importance of identifying and reporting the LVR variations in these patients.

Since our study was based on the evaluation of PET/CT images which were readily obtained in our daily practice of oncological imaging, we did not use MRI or CT angiography for comparison. Several studies were conducted with CT or CT angiography in order to obtain the percentages of LRV variations [2, 4, 8-11]. In a study with multidetector CT angiography, total LRV variations were detected in 68 (3.6%) of the 1856 patients [10]. In a newer study with the same modality mentioned above, the percentages of RLRV and CLRV were 2.1%, 30/1452 and 2.1%, 31/1452, respectively [8]. By using routine abdominal CT scans, LRV variations were identified in 23 (3.1%) of 739 cases [11]. In a large-scale study with contrast-enhanced abdominal helical CT [2], the percentages of the total LRV variations, RLRV and CLRV were reported as 5.2%, 3.1%, and 2.1%, respectively. Though we did not use intravenous contrast media, the percentages that we obtained utilizing PET/CT are close to those of above mentioned contrast-enhanced studies. Our results are also comparable to those obtained by using MRI [1], in which the percentage of total LRV variations was reported as 2.68%. Our results are also within the range stated in an analysis of a vast range of percentages obtained from several studies [3]. Regarding the possible unfavourable surgical and clinical outcomes, these variations were not thought be "rare" [1]. After evaluating our results and those obtained from previous studies with other imaging modalities, we consider that abdominal PET/CT images can be used in the identification of LRV variations. Thus, we recommend to look for and report these variations in daily PET/CT practice.

In imaging studies performed with CT [4, 7, 8] and MRI [1], no significant relationship between gender and LRV variations was reported as in the present study for the most common variations of RLRV and CTRV.

Because a relatively limited number of patients population could be recruited during the 18 months study period and since intravenous contrast-enhanced CT or CT anjiography images were not obtained during our PET/CT practice, we could not clearly identify other types of LRV variations, different from RLRV and CLRV. This can be accepted as a limitation of our study. We suppose that further studies with PET/CT including larger and different patient groups will follow. We considered that the number of our patients was sufficient to demonstrate the usefulness of PET/CT in identifying these two most frequent, clinically important LRV variations. Using all consecutive images, careful tracking of LRV uninterruptedly-from renal hilus to IVC-helped us to identify RLRV and CLRV correctly. The lack of intravenous contrast material was partially compansated by ^{18}F-FDG accumulated in left renal pelvis and in proximal left ureter, which had a contrast effect similar to iodinated contrast media in the pyelogram phase and helped us distinguish these structures from adjacent LRV. In each case, LRA was also followed from abdominal aorta to left renal hilus in order to differentiate it from LRV. In available patients, hyperdense atheromatous calcifications were also helpful in determining the origin and course of renal arteries.

In conclusion, according to the results of our original paper, routine abdominal PET/CT images are useful in detecting RLRV and CLRV. The relationship of gender with RLRV or CLRV was not statistically significant.

The authors declare that they have no conflicts of interest

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