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Diagnosis of Nutcracker Syndrome of the Left Renal Vein:
Value of the Corticomedullary Phase of Helical CT

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左腎静脈ナットクラッカー症候群の診断：
ヘリカルCTでの造影早期相(皮質造影相)の
有用性の評価

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左腎静脈ナットクラッカー症候群の診断においてヘリカルCTでの後腹膜静脈の早期濃染の臨床的意義を評価した．原因不明の血尿患者38人を対象に造影ヘリカルCT，逆行性左腎静脈造影および左腎静脈・下大静脈圧測定を施行した．ナットクラッカー症候群の側副血行路の検出能を腎ヘリカルCTでの早期相(皮質造影相)および後期相(実質相)にてそれぞれ評価した．ナットクラッカー症候群は腎静脈造影および静脈圧測定にて19人(50%)であった．そのうち12人は側副血行路のある左腎静脈高血圧で，1人は側副血行路のない左腎静脈高血圧，6人は側副血行路があり，静脈圧は正常，または境界域であった．左腎静脈のヘリカルCT造影早期相(皮質造影相)での平均CT値は164±22 Hounsfield unit(H)，範囲は138〜209Hで，後期相(実質相)では80±14H，範囲は62〜100Hで早期相が有意に(P < 0.001)高値を示した．側副血行路の逆流は早期相にて側副血行路がある18人中15人(83%)，後期相にて8人(44%)それぞれ検出できた．側副血行路の描出を診断基準とするとナットクラッカー症候群に対する造影CT早期相の感度は79%，特異度は100%であった．後期相では感度42%，特異度100%であった．ヘリカルCTでの造影早期相(皮質造影相)では左腎静脈から側副血行路への逆流がよく示され，左腎静脈ナットクラッカー症候群の診断に後期相(実質相)より有用である．

INTRODUCTION

Compression of the left renal vein (LRV) between the aorta and the superior mesenteric artery results in LRV hypertension. This LRV hypertension, also called the nutcracker syndrome, is possibly associated with three clinical manifestations: unilateral hematuria, gonadal vein syndrome, and varicoceles[1]. In the absence of any other detectable pathology, left sided hematuria will raise suspicion of nutcracker syndrome. However, asymptomatic mesoaortic compression of the LRV is probably common, as is suggested by the 51%-72% prevalence of distended LRVs noted by CT or sonography[2,3]. Both retrograde left renal venography and measurement of the pressure gradient between the LRV and the inferior vena cava (IVC) are the procedures of choice to establish the diagnosis of this syndrome in patients with unexplained hematuria on the left side [4,5]. Recently, color Doppler imaging is useful in the diagnosis of nutcracker syndrome when the demonstration of color flow in collateral veins was included in the diagnostic criteria[6]. Sonography can easily depict increasing volume and velocity of blood flow in gonadal and retroperitoneal collateral veins.

Helical CT has many advantages over conventional axial CT: faster scanning, acquisition of scan exclusively during peak levels of contrast enhancement, and reconstruction of scans at overlapping intervals. The kidneys can be visualized during the three distinct phases of renal enhancement: the earlier corticomedullary phase, when there is peak corticomedullary differentiation; the later nephrographic phase, when the nephrogram is homogeneous; the excretory phase[7]. Early scanning during the corticomedullary phase will maximize depiction of vascular anatomy and optimize imaging of the adjacent organs; later scanning during the nephrographic phase will optimally characterize the enhancement pattern of the lesion in question and increase the detection of smaller lesions[8]. However, there have been no reports investigating the usefulness of helical CT for the detection of nutcracker syndrome.

In this study, the role of helical CT was evaluated in the diagnosis of this syndrome.

PATIENTS AND METHODS

Patients Population

Between November 1997 and March 1999, 38 patients were referred for evaluation of gross hematuria of unknown origin from the urologic clinics of our four related hospitals. They included 12 men and 26 women, who were 18 to 32 years old (mean, 24 years) and had had gross intermittent hematuria for 1 month to 2 years (mean, 11 months). All patients underwent helical CT of the kidneys, retrograde left renal venography, and measurements of renocaval pressure gradients. In all cases, nonrenal causes of hematuria, such as urolithiasis, infection, or neoplasm, were excluded by medical and urological examinations. Cystoscopic examinations confirmed left-sided hematuria in 26 patients and indeterminate-site hematuria in 12. Urinalysis in 18 of the 38 patients showed red blood cells that appeared morphologically similar to those in peripheral blood vessels. Urine cytology indicated class I in all patients. Imaging studies before helical CT and angiographic examinations included excretory urography (n = 38), conventional CT with and without intravenous administration of contrast agent (n = 20), color Doppler imaging (n = 14), and scrotal sonography (n = 10). Excretory urography revealed left ureteral notching in three patients with left-sided hematuria. CT of kidneys revealed distended LRVs in 16 patients, 4 of whom had enlarged left gonadal veins. No other abnormality was found in the kidneys. Color Doppler imaging showed color flow of collateral veins in 9 of the 14 patients tested. Of the 12 male patients, 8 with left-sided hematuria had testicular varicoceles shown on scrotal sonography.

CT Imaging Techniques

Helical CT scan of the kidneys was performed both before and after IV injection of contrast agent. Helical scans were acquired using a helical CT with a Lemage SX scanner (Yokogawa Medical System, Tokyo, Japan). The upper and lower margins of the kidneys were determined from preliminary axial images. Before IV administration of contrast agent, helical-mode images of the kidneys were obtained, with a collimation of 5 mm and a pitch (ratio of table speed to collimation) of 1. Scan parameters were 200-250 mA at 120 kVp. Helical scans were reconstructed using 180-degree linear interpolation with spacing equal to the collimation. Images were acquired during a single 30-to 40-sec breath hold by the patient. Subsequently, a total dose of 100 mL (1.4 - 2.0 mL/kg) nonionic contrast media, iopamidol (Iopamiron 300, Schering, Berlin, Germany) was administrated at a rate of 3 mL/sec using an automated mechanical injector (Autoenhance

A 50, Nemotokyourindo, Tokyo, Japan). For the corticomedullary phase, the scan delay was 40 sec from the injection of contrast agent to the initiation of scanning. The nephrographic phase image was obtained with comparable scan parameters and a delay of 120 sec from the bolus injection of contrast agent.

Angiography and Renocaval Pressure Measurements

Retrograde left renal venography was performed using digital subtraction angiography with an Angiostar system (Siemens, Iselin, NJ). A double-curved 5 French catheter was used for retrograde left renal venography and measurement of pressure. Mean pressure of the LRV and pullback pressure from the LRV to the IVC was measured in mmHg with the patient in a supine positioned and the transducer position at the right atrial level. The pressure gradients were classified as normal gradient, less than 1 mmHg; borderline hypertension, 1 to less than 3 mmHg; and hypertension, 3 mmHg and higher[6]. The mean pressure in the vessels was automatically traced with an amplitude of which 1 mm was equivalent to 0.1 mmHg. Left renal venogram was obtained after the catheter was reintroduced into the LRV. For the venogram, a 20-ml dose of contrast agent was injected at the rate of 10 ml/sec. The findings of retrograde left renal venograms were categorized into venous flow with or without collateral veins. Collateral veins on the venograms were defined as tortuous veins in gonadal, ascending lumbar, adrenal, periureteral, capsular, or intrarenal veins.

CT Imaging Analysis

Both the corticomedullary and nephrographic phases of enhanced helical CT images in combination with unenhanced helical CT images were reviewed separately by two of radiologists (HI, ST). The observers were blinded to the results of the other imaging studies, clinical histories, and laboratory data. Additionally, they interpreted the scans independently. When disagreements occurred, the observers discussed the findings and reached a consensus opinion. The CT images were evaluated LRV flow pattern in relation to the diameter of the LRV, localization of collateral veins, and contrast enhancement of both the LRVs and collateral veins. The diameters of the distal LRVs (lateral to the aorta) and proximal LRV (in front of the aorta) were measured. Subsequently, the ratio of 1.5 for the diameter of the distal LRV to that of the proximal LRV was chosen as the cutoff level for distension[2]. Collateral veins on helical enhanced CT were identified as veins that had retrograde flow from the LRV. The flow patterns of LRVs were classified according to the presence or absence of collateral veins. The attenuation values of the LRVs were determined by calculating the mean flows of three separate regions of interest (at least 0.4 cm^2) during both the corticomedullary and nephrographic phases of enhanced helical CT. The mean LRV attenuations were com-

pared between corticomedullary phase and nephrographic phase, and paired Student's t test was employed to determine whether there was a significant difference between the two phase. A difference was considered to be significant when the P value was less than 0.05. The final diagnosis of nutcracker syndrome was based on both LRV flow patterns on the venograms and renocaval pressures. The sensitivity and specificity of the corticomedullary- and nephrographic- phase imaging for revealing the nutcracker syndrome were determined by analyzing pressure gradients combined with the venograms, which were used as the gold standard.

RESULTS

### Retrograde Venography and Pressure Gradients

Retrograde venography revealed collateral veins in 18 patients (47 %) and no collateral veins in 20 (53 %). The 18 patients had multiple collateral veins that were gonadal veins (n = 12), retroperitoneal veins connecting to ascending lumbar veins (n = 8), adrenal veins (n = 8), capsular veins (n = 2), periureteral veins (n = 3), and intrarenal varices (n = 3). Renocaval pressure gradients were normal in 13 patients, showed borderline hypertension in 19, and indicated hypertension in 6. Of the 18 patients with collateral veins, 5 had LRV hypertension, and 12 had borderline hypertension. Of

the 20 patients without collateral veins, 1 had LRV hypertension, and 7 had borderline hypertension. Using venography combined with pressure measurements, I diagnosed nutcracker syndrome in 19 patients: 12 with LRV hypertension with collateral veins, 1 with hypertension without collateral veins, and 6 with collateral veins with normal pressure gradients or borderline hypertension. Two patients with borderline hypertension but no collateral veins were excluded from the diagnosis of nutcracker syndrome.

Helical CT

Both corticomedullary- and nephrographic- phase images revealed distended LRVs in 26 (68 %) of the 38 patients. No difference in LRV diameter of the LRV was observed between the corticomedullary and nephrographic phases. The mean diameter and the mean distal-to- proximal diameter ratio of the 26 distended LRVs were 10 ±2 mm (range, 6 to 16) and 4.4 ± 1.2 (range, 1.3 to 8.0) respectively. Those of the 12 nondistended LRVs were 6 ±2 mm (range, 3 to 9) and 1.2 ± 0.2 (range, 1.1 to 1.3) respectively.
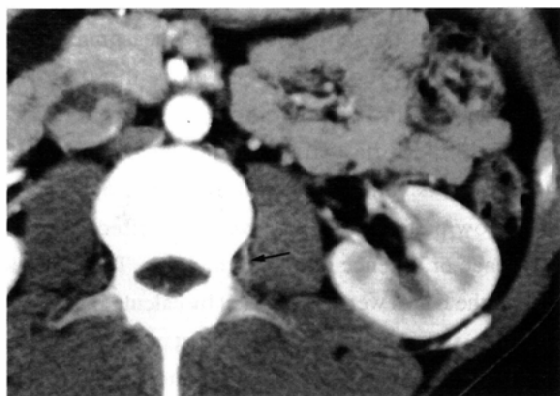
The corticomedullary phase of helical scans revealed intense enhancement of the LRVs in all patients (Fig. 1-A), whereas the nephrographic phase failed to show optimal LRV enhancement in all patients. The mean attenuation values of LRV in the corticomedullary phase (164 ± 22 Hounsfield units (H), range 138-209 H) was significantly greater (P < 0.001)
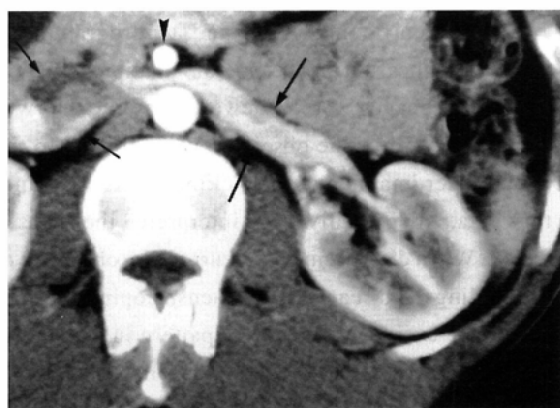
(A)

(B)

(C)

Fig. 1 A 26-year-old man with left-sided hematuria.
A: Corticomedullary-phase image of enhanced helical CT reveals optimal enhancement in distended left renal vein (arrows) due to compression of the proximal portion between the aorta and superior mesenteric artery (arrowhead). Note heterogeneous enhancement in the IVC (short arrows).
B: Corticomedullary-phase image 1-cm caudal to (A) reveals early enhancement, indicating retrograde flow in a confluence of the retroperitoneal collateral vein (arrow), which communicates with a small vein (arrowhead) running along the vertebral body.
C: Corticomedullary-phase image 1-cm caudal to (B) reveals early enhancement in the left ascending lumbar vein (arrow), which communicates with the retroperitoneal collateral vein on (B). Renocaval pressure gradient is 1.5 mmHg, which is categorized as borderline hypertension. Assessment of nutcracker syndrome was long-term with compensatory status.

than the value for the nephrographic phase (80 ±14 H, range, 62-100 H). The difference was statistically significant. During the corticomedullary phase, opacified blood from the renal vein is mixed with unopacified blood in the IVC. On the nephrographic phase, however, the IVC was enhanced homogenously, but only slightly. The corticomedullary-phase imaging detected collateral veins that had early enhancement, indicating retrograde flow from the LRVs in 15 patients (83 % of those with collateral veins). The collateral veins observed were either retroperitoneal veins connecting to the ascending lumbar veins (n = 9, Fig. 1-B, C, Fig. 2) or gonadal veins (n = 12, Fig. 3). However, imaging failed to distinguish capsular, adrenal, periureteric, and intrarenal collateral veins. Gonadal veins that had no early enhancement on the corticomedullary phase were not revealed as collateral veins on the retrograde venograms. Nephrographic-phase imaging revealed collateral veins in 8 patients (44 % of those with collateral veins). The collateral veins were limited to dilated gonadal veins in which retrograde flow was shown when the veins were enhanced as same as the left renal vein (Fig. 1-A, B). The imaging failed to distinguish other collateral veins including retroperitoneal collateral veins connecting with ascending lumbar veins.

When the demonstration of collateral veins was included in the diagnostic criteria, a false negative for the corticomedullary phase was observed in 4 patients, 3 of whom had only periureteric collateral veins, adrenal collateral veins, or intrarenal varices, and one of whom had no collateral veins but did have LRV hypertension. In addition to these 4 patients, 11 others were judged false negative for nutcracker syndrome

on nephrographic-phase imaging. Neither corticomedullary- nor nephrographic-phase imaging led to any false-positive diagnoses of the syndrome. The sensitivity and specificity of the corticomedullary-phase scan for revealing the nutcracker syndrome were 79% and 100% respectively. In contrast, those of the nephrographic phase were 42% and 100%.

DISCUSSION

The nutcracker syndrome occurs in relatively young, previously healthy patients and is characterized by intermittent gross hematuria due to LRV hypertension[9]. The hematuria associated with nutcracker syndrome is thought to occur when increasing LRV pressure causes minute ruptures of thin-walled veins into collecting system or renal fornix[10] or causes communication between dilated venous sinuses and adjacent renal calyces[11]. Beinart et al.[4] defined a pressure of 1 mmHg or more as indicative of LRV hypertension. However, Nishimura et al.[5] claimed that 3 mmHg or more indicates LRV hypertension. I believe that a classification including borderline LRV hypertension (1- < 3 mmHg) should be accepted because there has been no uniform agreement for the cut off level of the pressure gradient for LRV hypertension[6].

A diagnosis of nutcracker syndrome must relate to a whole spectrum of findings because the flow patterns in the LRVs depend on the degree and stage of the syndrome[6]. Distended LRVs can be a normal variation without collateral veins and with a normal pressure gradient. The distinction between normal variation and early sign of nutcracker syndrome is difficult in patients with borderline LRV hypertension. Per-

Fig. 2 A 36-year-old woman with left-sided hematuria.
Corticomedullary phase of enhanced helical CT image 1-cm caudal to a distended left renal vein (not shown) reveals early enhancement of a retroperitoneal collateral vein (arrow) connecting to a distended ascending lumbar vein (short arrow).
Renocaval pressure gradient is 3.8 mmHg, which is categorized as left renal vein hypertension. Assessment of nutcracker syndrome was long-term with noncompensatory status.

Fig. 3 A 21-year-old woman with left-sided hematuria.
Corticomedullary-phase image 1-cm caudal to a distended left renal vein (not shown) reveals early enhancement in a distended gonadal collateral vein (arrow).
Renocaval pressure gradient is 4.5 mmHg, which is categorized as left renal vein hypertension. Assessment of nutcracker syndrome was long-term with noncompensatory status.

sistence of LRV hypertension probably causes the development of collateral veins. However, well-developed collateral veins dissipate a high pressure gradient and diminish the blood flow volume of the LRV, which result in the absence of distended LRV and LRV hypertension.

The detection of retrograde flow from the LRV to the collateral veins is a useful finding in diagnosing nutcracker syndrome. Conventional CT can reveal normal-caliber gonadal veins, which can be traced on consecutive contrast-enhanced scans in a majority of patients[12]. However, conventional CT cannot assess the direction of blood flow or the distinction of collateral veins from enlarged gonadal veins in multiparous women without nutcracker syndrome. The rapid acquisition of helical CT allows for much finer control over the phase of intravascular contrast enhancement that is imaged than does conventional CT, and thus different vascular information is obtained depending on the mode of contrast administration and the scan delay time. Early scan of the corticomedullary phase has been recommended to be delayed to approximately 30 to 70 sec after starting the bolus administration of contrast agent[7], [13], [14]. The corticomedullary phase of helical CT begins as contrast material enters the corticomedullary capillaries and peritubular spaces and filters into the proximal corticomedullary tubules[15], [16].

With helical CT, corticomedullary phase can show the peak enhancement of the renal vein as well as that of the renal artery. On selective renal angiography, optimal venous contrast enhancement follows the nephrographic arteriography phase and is obtained within the 10 to 14 sec after peak-enhancement of renal arteries[17]. Approximately 20% of the contrast medium is filtered before entering the renal vein[17]. However, poor but prolonged venous opacification partially reflects the varying rates of blood flow in the cortex, outer medulla, and inner medulla[17]. The CT corticomedullary phase requires for 30 to 40 sec of scan time and includes arteriographical arterial, nephrographic, and venous phases. A larger amount of contrast material infused in helical CT results in an overlap of the optimal enhancements in the renal arteries, cortex, and veins. Therefore, corticomedullary-phase imaging in helical CT easily reveals retrograde flow from the LRV to the collateral veins but is limited to the flows in gonadal veins and retroperitoneal veins to the ascending lumbar vein. The flows in adrenal collateral veins, periureteric and capsular collateral veins, and intrarenal varices are difficult to demonstrate because the small collateral veins may be hidden by other structures.

The nephrographic phase begins as contrast material proceeds from the corticomedullary vessels into the extracellular-interstitial space[18]. Onset of this phase is highly dependent on the method of contrast material administration and

patient characteristics such as age and weight, and thus onset varies from 60 to 136 sec from the begining of the bolus injection of contrast agent[18]. In this present study, I obtained nephrographic phase scans with a delay of 120 sec, which was sufficient to discriminate it from the corticomedullary phase but may have resulted in an overlap with the excretory phase. The early nephrographic phase may show residual early enhancement indicating retrograde flow in long and dilated gonadal veins although such enhancement is not optimal.

Corticomedullary-phase imaging is superior to nephrographic-phase imaging for the detection of the collateral veins in nutcracker syndrome. Empirically, the findings of both dilated LRV and dilated gonadal veins may suggest the presence of nutcracker syndrome on the nephrographic or excretory phase. However, the presence of retrograde flow from the LRV to the collateral veins on the corticomedullary phase is a reliable indicator of nutcracker syndrome. A confluence of retroperitoneal collateral vein communicating with left ascending lumbar vein may be mistaken for a paraaortic lymphadenopathy[19]. The corticomedullary phase of renal enhancement has many benefits: tumor vascularity, differentiating prominent columns of Bertin or dromedary humps from renal mass[8], detecting renal cell carcinomas in end-stage kidneys[20], and noting asymmetries in renal perfusion resulting from renal arterial stenosis[8], [21]. However, imaging during the corticomedullary phase with helical CT may actually obscure pathology because the normal medulla may be difficult to separate from a mass or other pathologic conditions[7], [13], [14]. Furthermore, a small, hypervascular renal cell carcinoma may not be identified during the corticomedullary phase because it may have a similar enhancement effect as that of normal renal cortex[22]. Therefore, renal helical CT studies should include at least one data acquisition during the homogeneous nephrographic phase of renal enhancement[7], [13], [14].

As with the corticomedullary phases of helical enhanced CT, color Doppler imaging is also a useful technique for the detection of gonadal veins and retroperitoneal veins. Blood flow in a collateral vein is revealed as color flow away from the LRV. The flows of markedly tortuous collateral veins are composed of color flow both away from and toward the LRV[6]. This Doppler technique, which is inexpensive and available in most hospitals, is not uncomfortable for the patient and does not use radiation. However, the relations to surrounding structures, such as the connection of retroperitoneal veins to ascending lumbar veins, are depicted more easily on CT images than on color Doppler images. Detection of nutcracker syndrome sometimes requires a combination of color Doppler imaging and the corticomedullary-phase helical CT imaging. I believe that both helical enhanced CT and color Doppler sonography will replace retrograde left renal venog-

raphy and pressure measurement as preferred methods for the diagnosis of nutcracker syndrome. I recommend that corticomedullary-phase imaging for detecting nutcracker syndrome should be used in conjunction with nephrographic-phase imaging for detecting small renal masses in patients with left-sided hematuria of unknown origin.

References

1) Dever DP, Ginsburg ME, Millet DJ, et al: Nutcracker phenomenon. Urology 27: 540–542, 1986

2) Buschi AJ, Harrison RB, Brenbridge ANAG, et al: Distended left renal vein: CT/sonographic normal variant. AJR 135: 339–342, 1980

3) Zerin JM, Hernandez RJ, Sedman AB,et al: Dilatation of the left renal vein on computed tomography in children: a normal variation. Pediatr Radiol 21: 267–269, 1991

4) Beinart C, Sniderman KW, Tamura S, et al: Left renal vein to inferior vena cava pressure relationship in humans. J Urology 127: 1070–1071, 1981

5) Nishimura Y, Fushiki M, Yoshida M, et al: Left renal vein hypertension in patients with left renal bleeding of unknown origin. Radiology 160: 663–667, 1986

6) Takebayashi S, Ueki T, Ikeda N, et al: Diagnosis of the nutcracker syndrome with color Doppler sonography: correlation with flow patterns on retrograde left renal venography. AJR 172: 39–43, 1999

7) Cohan RH, Sherman LS, Korobkin M, et al: Renal masses: assessment of corticomedullary-phase and nephrographic-phase CT scans. Radiology 196: 445–451, 1995

8) Urban BA: The small renal mass: what is the role of multiphasic helical scanning? Radiology 202: 22–23, 1997

9) Kim SH, Cho SW, Kim HD, et al: Chung JW, Nutcracker syndrome: diagnosis with Doppler US. Radiology 198: 93–97, 1996

10) Lopatkin NA, Morozov AV, Lopatkina LN: Essential renal haemorrhages. Eur Urol 4: 115–119, 1978

11) Low AI, Matz LR: Haematuria and renal fornical lesions. Br J Urol 44: 681–691, 1972

12) Lee JKT, Heiken JN, Semelka RC: Retroperitoneum. In: Lee JKT, Sagel SS, Stanley RJ, Heiken JP, eds. Computed body tomography with MRI correlation. 3rd ed. Philadelphia, Lippincott-Raven 1023–1086, 1998

13) Birnbaum BA, Jacobs JE, Ramchandani PR: Multiphasic renal CT: comparison of renal mass enhancement during the corticomedullary and nephrographic phases. Radiology 200: 753–758, 1996

14) Zeman RK, Zeiberg A, Hayes WS, et al: Helical CT of renal masses: the value of delayed scans. AJR 167: 771–776, 1996

15) Saunders HS, Dyer RB, Shifrin RY, et al: Scharling ES, The CT nephrogram: implications for evaluation of urinary tract disease. RadioGraphics 15: 1069–1085, 1995

16) Hattery RR, Williamson B Jr, Hartman GW, et al: Intravenous urographic technique. Radiology 167: 593–599, 1988

17) Bookstein JJ: Angiography of the genitourinary tract: techniques and applications. In: Pollack HM, ed. Clinical urography. Philadelphia: Saunders 456–496, 1990

18) Birnbaum BA, Jacobs JE, Langlots CP, et al: Assessment of a bolus-tracting technique in helical renal CT to optimize nephrographic phase imaging. Radiology 211: 87–94, 1999

19) Meanock CI, Ward CS, Williams MP: The left ascending lumbar vein: a potential pitfall in CT diagnosis. Clin Radiol 39: 565–566, 1988

20) Takebayashi S, Hidai H, Chiba T, et al: Using helical CT to evaluate renal cell carcinoma in patients undergoing hemodialysis:value of early enhanced images. AJR 172: 311–315, 1999

21) Rubin GD, Silverman SG: Helical (Spiral) CT of the retroperitoneum. Radiol Clin North Am 33: 903–948, 1995

22) Hertz BR, Einstein DM, Paushter DM: Spiral CT of the abdomen: artifacts and potential pitfalls. AJR 161: 1185–1190, 1993

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