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A PICTORIAL PRESENTATION OF CT KIDNEY LESIONS IN ADULTS, PARTICULARLY KIDNEY CANCER: PART 1

Joel Harold Bortz[1] *MB ChB [Cape Town]; DMRD [London]; FRCR [London]; FFRRCS [Ireland]*
Riaan van de Venter[2] *DRad, MTech:Rad (research), PDTE*
Leonie Munro[3] *ND Rad (D), MA, P Grad Dip: Public Admin, Cert for trainers*

[1]LSG Imaging, Los Angeles, California, America
[2]Lecturer, Nelson Mandela University, Port Elizabeth, South Africa
[3]Durban, South Africa

ABSTRACT
There are many pathologies that affect the kidneys. The focus of this paper is computed tomography of kidney cancer. Other imaging modalities for kidney pathologies are briefly discussed. A few examples of benign tumours and masses are presented. The bulk of the paper is a pictorial presentation of kidney cancer and its spread to other organs and bones. A range of unenhanced and enhanced CT images are included for self-assessment.

Keywords: renal cell carcinoma, lymphadenopathy, oncocytoma, imaging modalities

LAY ABSTRACT
Imaging of the kidneys is done to find out whether a mass in a kidney may be a benign tumour, cyst or cancer. If it is a cancer then it is important to check whether there is spread to other organs. Examples of computed tomography (CT) are used to describe the different patterns of benign and cancer lesions.

1. INTRODUCTION

Kidney pathologies may be congenital, such as horseshoe kidney, or acquired, such as renal tumours.[1] The latter may be benign or malignant. Kidney cancer affects all age groups. In adults it is the sixth most common cancer in men, and the eighth most common in women.[2, 3] Radiology plays an important role in imaging of kidney cancer as there are no routine screening tests for early detection of kidney cancer.[4]

The focus of this paper is on computed tomography (CT) images of cancer of the kidney in adults, excluding hereditary kidney cancers and kidney cancer in children.

Knowledge of anatomy of the kidney is important when interpreting CT images. Other modalities are used to visualise kidney pathology. A brief overview is presented of those that may be used for kidney cancer patterns.

The bulk of the paper is of CT images of kidney cancer and its spread to other organs and bones. A pictorial presentation is used to illustrate the different CT patterns of kidney cancer. It is important to also recognise the patterns of cysts and benign tumours therefore several examples of these pathologies are presented. Table 1 presents the headings and sub-headings of this article. Box 1 presents the objectives of this paper.

The article is presented in five parts. The references are listed in Part 5.

Table 1. Headings and sub-headings

Number	Heading	Sub-heading
1	Introduction	
2	Anatomy	
3	Definitions	
4	Overview of imaging modalities to visualise kidney pathology	4.1 Plain-film abdominal radiography 4.2 Ultrasonography 4.3 CT 4.4 MRI 4.5 Nuclear medicine
5	Kidney cancer: risk factors and treatment	5.1 Benign tumours vs RCC 5.1.2 Angiomyolipoma (AML)
6	Renal lesions: CT of the abdomen	6.1 Malignant renal tumours 6.2 Role of unenhanced CT for visualisation of renal lesions

Table 1 continued ...

Number	Heading	Sub-heading
7	Varied appearances of kidney cancer on CT	7.1 Small versus large tumours 7.2 Chromophobe and papillary RCC 7.3 Collecting duct cancer 7.4 Intrarenal transitional cell carcinoma 7.5 Metastases to the kidney 7.6 Transitional cell carcinoma (TCC) 7.7 Anatomic extent of tumour
8	Renal cysts and renal malignancies	
9	Lymphoma	
10	Multiphase CT for examination of the abdomen for lesions in the kidney and spread to adjacent organs	
11	Pictorial presentation of enhanced CT cases of kidney lesions and spread to other regions	11.1 Tips to evaluate 2D CT images for cancer of the kidney 11.2 Lungs and ribs 11.3 Liver 11.4 Spleen and pancreas 11.5 Venous system 11.6 Kidneys 11.7 Adrenal glands 11.8 Lymph nodes 11.9 Bony structures 11.10 Post-nephrectomy patients
12	Kidney cancer treatment, fusion imaging and dual energy CT	
13	Key points	
14	Conclusion	
15	Self-assessment	

Box 1

Nine objectives underpin the overarching aim of this paper, which is to provide a range of CT images for radiographers to be able to perform pattern recognition of normal kidneys, benign kidney pathology, kidney cancer and its spread, and post-nephrectomy cases.

- Present a summary of the anatomy of the kidney
- Provide a list of definitions that pertain to kidney lesions and CT of the kidney
- Provide examples of benign kidney masses
- Present a summary of different imaging modalities for kidney pathology
- Briefly discuss causes of cancer of the kidney and its spread
- Discuss the use of multiphase CT for examination of the abdomen for lesions in the kidney and spread to adjacent organs
- Provide tips on how to evaluate CT images of kidney cancer and its spread
- Present a range of un-enhanced and enhanced CT images showing benign and malignant kidney tumours
- Provide a range of CT images for self-assessment

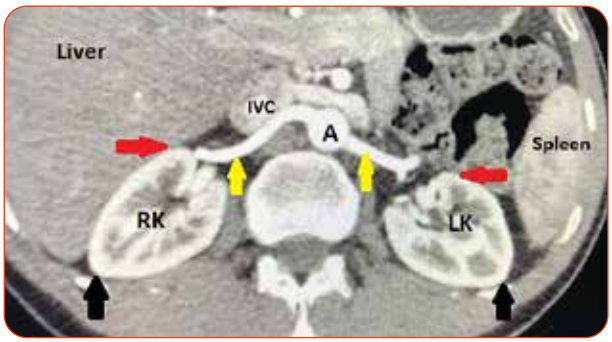

Figure 2.1. Axial CT scan showing right kidney (RK) and left kidney (LK). Right renal artery (yellow arrow) and left renal artery (yellow) arise from the aorta (A). The upper poles are deviated medially (red arrows) and the lower poles laterally (black arrows). Inferior vena cava = IVC.

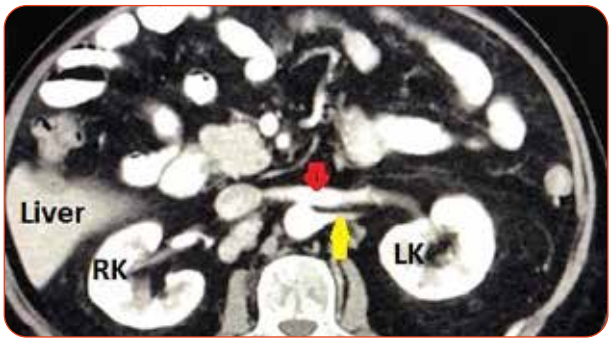

Figure 2.2. Axial CT scan showing right kidney (RK), left kidney (LK), left renal vein (red arrow), and renal artery (yellow arrow).

Figure 2.3a. Unenhanced axial CT scan showing right kidney (RK) and left kidney (LK). Left renal vein (white arrow) is above the aorta (A).

Figure 2.3b. Unenhanced axial CT scan showing left renal vein below the aorta. Green arrow = IVC.

Figure 2.4a. Unenhanced axial CT scan showing the adrenal glands above the kidneys. Right adrenal (black arrow) and left adrenal (red arrow). RK = right kidney, LK = left kidney, Aorta = A.

Figure 2.4b. Enhanced axial CT scan showing the right adrenal (red arrow) and aorta (A).

2. ANATOMY

The kidneys normally lie on either side of the vertebrae in the abdomen. They are paired retroperitoneal bean-shaped organs. There are three distinct spaces in the retroperitoneum, namely, anterior and posterior para-renal spaces, and the perinephric space. The latter has an inverted cone shape which contains the kidneys, proximal ureters, adrenal glands, vessels and lymphatics.[5] The upper poles of the kidneys are deviated medially and the lower ones laterally (Figure 2.1).[1] The right kidney is below the liver. It is lower than the left kidney.[1] The renal artery and vein, ureter and nerves enter the kidney via the hilum at the level of the first lumbar vertebra.[1] Figure 2.2 shows the renal arteries which are below the renal vein.[6]

In approximately 3% of the population the left renal vein is retroaortic.[6] Figures 2.3a and b are unenhanced CT scans showing the normal position of the left renal vein and a retroaortic left renal vein. As shown in Figure 2.4a the suprarenal glands (adrenals) are in the perinephric space and are situated on top of each kidney.[1,5] Figure 2.4b shows an enhanced right adrenal gland. The right adrenal on CT has an inverted y-shape with two limbs and the left has a lambda shape and two limbs.

3. DEFINITIONS

- Adenopathy means any inflammation or disease that involves lymph nodes or glandular tissue. It usually refers to swollen lymph nodes or lymphadenopathy.[7]
- Angiomyolipoma is a benign tumour of the kidney. It comprises blood vessels (angio), muscle (myo) and fat (lipoma).[8]
- Benign is the opposite of malignant; it refers to a non-cancerous tumour that does not spread to other organs or parts of the body.[9]
- Cancer is the opposite of benign as the neoplastic cells can spread and metastasise. Renal cell cancer (RCC) occurs in the renal tissue that filters blood and produces urine. Transitional cell cancer occurs in the renal pelvis.[10]
- Cannonball lesions refer to well-circumscribed, spherical, metastatic lesions found in the lung fields. This is typical of haematogenous spread of malignancies.[11]
- Contrast enhanced CT (CECT) scan refers to a CT scan examination during which one or more contrast agents are administered to a patient in order to visualise and differentiate between different normal and abnormal tissues and viscera.[12]

- Cyst refers to closed cavity (sac/pouch) lined by epithelium and containing fluid.[13] A kidney cyst is a fluid-filled sac. There are two types: simple cyst or complex cyst that contains semisolid material.
- Hounsfield unit refers to x-ray attenuation coefficients of tissue compared to water on a CT scan. On the Hounsfield scale water is assigned a value of 0 HU; air has a value of -1000 HU; dense bone +1000 HU; fatty tissue of approximately -100 HU.[14]
- Metastases refers to growth of abnormal cells distant from the primary site.[15] Kidney cancer may metastasise to adrenal glands, liver, chest, vertebrae, ribs, brain, for example.[16]
- Oncocytoma is a benign epithelial renal tumour.[17] It usually presents as a solid tumour with a central star-shaped (stellate) scar, but may have central cyst degeneration or multilocular cyst.[17]

4. OVERVIEW OF IMAGING MODALITIES TO VISUALISE KIDNEY PATHOLOGY

Plain-film radiography, ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI), and nuclear medicine (NM), are covered in this overview.

4.1 Plain-film abdominal radiography

Plain abdominal radiography is an easily accessible and quick imaging investigation for non-specific abdominal pain and can be used to visualise the size, shape and location of the kidneys.[18-20] However, accurate differentiation between the various abdomino-pelvic viscera and their associated pathologies is not possible due to a low inherent subject contrast on plain-film abdomens.[19] Ultrasound and CT are considered first-line imaging investigations for renal pathologies.[18,19]

4.2 Ultrasonography

US can demonstrate renal tissue well. One can readily demonstrate the renal parenchyma and pelvicalyceal system; but the ureters are not frequently seen. US can assist in determining the size of the kidneys and any obstruction to renal outflow, and is used to differentiate solid, cystic and complex masses/tissues as well as where they are located and their dimensions.[20, 21] US is not a reliable imaging modality to differentiate renal tumour sub-types.[22] Renal vasculature and associated conditions can be assessed and visualised using vascular and colour-flow Doppler US techniques.[19] US is readily available, cheap and regarded as a first-line investigation for renal tumour screening but is highly operator-dependent.[12, 22-24] It has limitations in terms of further characterisation of both solid tumours and staging of malignancy.[24] In view of these limitations CT and MRI should be used for screening and imaging of kidney cancer.[24]

4.3 CT

CT is considered the gold standard due to is ability to provide high resolution cross-sectional images of the area of interest in various body planes and the ability to differentiate benign from malignant masses, staging of malignancies, and providing in-depth information about the impact renal masses have on surrounding anatomy.[21, 22]

Renal pathologies, like renal neoplasia and cysts, can be investigated using CT. Contrast enhanced CT (CECT) is used to visualise kidneys, invasion of other organs, and lymphadenopathy, and also allows for differentiation of benign lesions such as renal cysts, and oncocytoma.[12] Imaging protocols should include both pre- and post-contrast images.[16] According to de Leon and Pedrosa[16] pre-contrast images are used to provide baseline attenuation values in regions of interest as well as to help identify the presence of fat, calcification, or haemorrhage. To provide more information scanning of the abdomino-pelvic region may also occur at various time settings after contrast medium administration by using biphasic, triphasic or four-phase imaging techniques. This allows the contrast media to be visualised in different parts of the vascular system and aids in better diagnosis of specific pathologies.[21] Imaging of smaller renal masses with CT has been reported to pose challenges.[22]

4.4 MRI

MRI is a useful imaging tool in characterising renal masses and for staging of neoplasia, as an adjuvant to US and CT. MRI appearances of renal masses assist in more accurate diagnoses and subsequent patient management. MRI is used when US and CT findings appear to be inconclusive and to assess renal tumours ≤20mm in diameter.[22] To achieve optimal characterisation of renal masses it is recommended that MRI protocols cover (i) techniques to ensure maximum soft-tissue contrast, and (ii) multiplanar imaging.[16]

4.5 Nuclear medicine

Nuclear medicine plays a role in imaging of renal pathology as isotope scans provide valuable information about renal anatomy and function. A DMSA (dimercaptosuccinic acid) scan provides information about renal size, location and shape in cases where congenital renal abnormalities/anomalies are investigated, and useful information related to acute pyelonephritis and renal scarring. The isotope 18F-fluorodeoxyglucose (18F-FDG) is used for positron emission tomography CT (PET/CT) for investigating renal masses that are metabolically active and sensitive to 18F-FDG uptake. However, some authors argue that 18F-FDG PET/CT should not be used as the primary diagnostic imaging modality due to its low sensitivity.[22] Single-photon emission computed tomography (SPECT-CT) using technetium-99m-sestamibi has demonstrated promise in accurately differentiating oncocytomas and hybrid oncocytic/chromophobe tumours from other RCC subtypes.[22]

REFERENCES

See Part 5.