The Treated Kidney: Computed Tomography (CT) And Magnetic Resonance (MR) Patterns

Poster No.: C-1536
Congress: ECR 2012
Type: Educational Exhibit
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Keywords: Abdomen, Kidney, MR, CT, Ablation procedures, Surgery, Neoplasia
DOI: 10.1594/ecr2012/C-1536

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Learning objectives

To illustrate the most frequent CT and MR imaging appearance of the treated kidney, after surgical and ablative treatments.

To review the most common postoperative complications and the most frequent recurrence patterns after renal surgical and ablative treatments.

To evaluate the most effective CT and MR imaging examination techniques in the evaluation of treated kidney.
**Background**

Surgical treatments for renal masses are divided into radical treatments (total nephrectomy) and conservative treatments (partial nephrectomy, radiofrequency ablation and cryoablation). CT and MR are commonly used for the follow-up of patients treated for renal masses.

We reviewed 356 cases of CT and MR examinations of patients with renal masses treated with total nephrectomy, partial nephrectomy, renal cryoablation and renal radiofrequency ablation, to illustrate CT and MR imaging patterns of the treated kidney, most common postoperative complications and most frequent recurrence patterns.
Imaging findings OR Procedure details

MATERIALS AND METHODS

356 patients treated with total nephrectomy, partial nephrectomy, renal cryoablation and renal radiofrequency ablation performed CT and MR follow-up between July 2004 and February 2011.

All MR examinations were performed with a 1.5T MR system (Philips Gyroscan Intera Power) using Gradient Echo (GRE) T1w, Turbo Spin Echo (TSE) T2w sequences with and without fat suppression (FS) and contrast-enhanced (ce) dynamic GRE FS-T1w sequence. Post contrast GRE FS-T1w images were also evaluated before and after digital subtraction procedures.

All the CT examinations were performed with a MDCT system (Toshiba Aquilion Multi 4), using unenhanced and post-contrast axial scans, associated to multiplanar reconstructions. Contrast enhanced images were acquired on "Early post-contrast phase" (40" after contrast agent injection) and on "Nephrographic-phase" (120" after contrast agent injection). Multiplanar reconstructions were created with an independent workstation (Vitrea, Vital).

We evaluated the following parameters: A. Morphology; B. Signal intensity (MR) or Density (CT) of the treated areas; C. Patterns of vascularization of the treated areas. We also evaluated the patterns of local recurrences and postoperative complications.

IMAGING FINDINGS

TOTAL NEPHRECTOMY

POSTOPERATIVE RETROPERITONEAL ANATOMY

After right nephrectomy, right colon and right hepatic lobe occupy the renal fossa. Second portion of duodenum and pancreatic head may assume a posterolateral position (Fig. 1).

After left nephrectomy, pancreatic tail assumes a more posterior position, approaching quadratus lumborum. Spleen shifts posteromedially. Proximal jejunum and the descending colon #ll the left renal fossa (Fig. 2).

PATTERNS OF RECURRENTCE

After nephrectomy, recurrent renal carcinoma appears as an enhancing mass in the surgical site. The recurrence often involves the quadratus lumborum and psoas muscles and can displace or invade nearby structures (Fig 3).
Retroperitoneal lymph node metastases appear in 7.6% of the patients after nephrectomy for renal cancer (Fig 3).

POSTOPERATIVE COMPLICATIONS

Fluid collection (hematomas or abscesses) may develop in the surgical bed (Fig. 4). With imaging alone, it may be difficult to differentiate an infected fluid collection from an uninfected one. Nevertheless, the presence of air bubbles, clinical symptoms and signs are suggestive of infection.

PARTIAL NEPHRECTOMY

Partial nephrectomy can be performed by open surgery or laparoscopically. The surgical techniques for partial nephrectomy are: segmental polar nephrectomy, wedge resection, transverse resection and enucleation (Fig. 5); the method used depends on the size and the location of the mass. Parenchymal defect may be sutured, sealed by hemostatic agents or filled with adjacent fat.

RENAI PARENCHIMAL CHANGES AFTER PARTIAL NEPHRECTOMY

Parenchymal changes depend mainly on surgical techniques and hemostatic methods. Most frequent CT/MR findings are postoperative granuloma, fat at the excision site, linear or stellate parenchymal scar and parenchymal defect.

Postoperative granulomas can be seen as a minimally enhancing lesion at the excision site, due to the development of a foreign body reaction against suture material, urine leakage or bleeding at the excision site. Their sizes decrease in the follow-up (Fig. 6).

Fat, when used as filling material, shows a pseudo-lesion at the parenchymal defect, characterized by low density on CT images and fat-like signal intensity on MR images, without enhancement on post contrast scans. (Fig. 7). The size of the fat-lesion tends to decrease on sequential controls.

A linear or stellate parenchymal scar is usually seen in patients with parenchymal closure without suture material, due to minimal granulation tissue at the excision site. The scar shows low density (CT) and low signal (MR), without enhancement. The size of the scar decreases on sequential imaging studies (Fig. 8).

Parenchymal defects can be seen in cases of enucleation of an exophytic mass, without contrast enhancement. Usually they show no significant interval change on sequential CT/MR studies (Fig. 9).

PATTERNS OF RECURRENTCE

Local recurrence patterns are the presence of a mass with enhancement, increasing in size during the follow-up, at the excision site or at the perinephric space (Fig. 10).
POSTOPERATIVE COMPLICATIONS

Commonly reported complications include urinary leak or fistula (Fig. 11), bleeding (Fig. 12), renal infection, ischemic changes in the renal parenchyma and ureteral or renal pedicle stricture.

RENAI CRYOABLATION

RC is considered a minimally invasive approach for the treatment of small renal masses.

The histologic sequelae of cryoablation are interstitial hemorrhage followed by minimal inflammatory reaction, coagulative necrosis with vascular congestion and pyknosis and finally fibrosis and scarring.

Since it is not possible to document histopathologically the complete tissue necrosis after cryoablation, an adequate radiological (MR-CT) follow-up is mandatory.

IMAGING PATTERNS

On MR and CT imaging 24 hours after treatment all cryolesions were more than 1 cm larger than the original masses. Treated areas tend to reduce in size over time during the follow-up.

In the MR imaging follow-up, cryolesions typically appear to be isointense on T1w images and hypo- or isointense on T2w images without any enhancement after gadolinium infusion (Fig. 13).

In the CT imaging follow-up, cryolesions typically appear to be heterogeneously iso-hypodense compared to renal parenchima, with relative hypodensity without any enhancement after contrast medium infusion (Fig. 14).

PATTERNS OF RECURRENCE

Local recurrence patterns are the presence of an enhancing nodule in the treated area, increasing in size during the follow-up (Fig. 15,16).

POSTOPERATIVE COMPLICATIONS

The most frequent post-operative complications in pts treated with LC are incomplete ischemia of cryolesion 24 hrs after surgery (Fig. 17) and intra-lesional and peri-lesional haematomas (Fig. 18).

RENAI RADIOFREQUENCY ABLATION

In radiofrequency ablation, a high-frequency, alternating current is emitted through an electrode placed within the renal lesion.
The deposition of radiofrequency energy induces heating of target tissue with temperatures sustained between 50° and 105°C, with protein denaturation, destruction of the cytoplasm and cell death.

IMAGING PATTERNS

Immediately after RF ablation, the ablated lesion is usually larger than the preablation tumor both on CT and MR imaging, with reduction in size over time during the follow-up.

In the MR imaging follow-up, cryolesions tipically appear to be isointense on T1w images and hypo- or isointense on T2w images without any enhancement after gadolinium infusion (Fig. 19).

In the CT imaging follow-up, cryolesions tipically appear to be heterogeneously iso-hypodense compared to renal parenchima, without any enhancement after contrast medium infusion (Fig. 20).

PATTERNS OF RECURRENCE

Local recurrence patterns are the presence of an enhancing nodule in the treated area, increasing in size during the follow-up (Fig. 21).

POSTOPERATIVE COMPLICATIONS

The most frequent post-operative complications in patients treated with radiofrequency ablation are incomplete ischemia of the lesion and peri-lesional haematomas.
Fig. 1: FIG. 1 RETROPERITONEAL ANATOMY AFTER RIGHT NEPHRECTOMY After right nephrectomy, the right colon occupies the renal fossa and second portion of duodenum and pancreatic head slide posterolaterally. Anatomic scheme before (A) and after surgery (B) (From Mu Sook Lee, AJR 2007). 67-year-old man who underwent right nephrectomy for renal cell carcinoma: CT before surgery (C) and CT (D: unenhanced, E: postcontrast images) and MR (F: T1w, G: T2w and H: ce FS GRE T1w images) imaging follow up 6 and 12 months after treatment.

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**Fig. 2:** FIG. 2 RETROPERITONEAL ANATOMY AFTER LEFT NEPHRECTOMY After left nephrectomy, the pancreatic tail assumes a more posterior position and spleen shifts posteromedially. Anatomic scheme before (A) and after surgery (B) (From Mu Sook Lee, AJR 2007). 72-year-old man who underwent left nephrectomy for renal cell carcinoma: CT before surgery (C) and CT (D: unenhanced, E: postcontrast images) and MR (F: T1w, G: T2w and H: ce FS GRE T1w images) imaging follow up 6 and 12 months after treatment.

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**Fig. 3:** FIG. 3 RECURRENCES AFTER NEPHRECTOMY 69-year-old man who underwent left nephrectomy for renal cell carcinoma: (A) ce-CT image showed an enhancing mass of the abdominal wall (red arrow), involving the lateral margin of the quadratum lumborum, associated to retroperitoneal lymph-nodal recurrence. (B) 71-year-old man who underwent right nephrectomy for renal cell carcinoma: ce-CT image showed retroperitoneal lymph-nodal recurrence.

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Fig. 4: FIG. 4 POSTOPERATIVE COMPLICATIONS AFTER NEPHRECTOMY 58-year-old woman with left renal cell carcinoma: (A,B) preoperative ce-CT images. Postoperative fluid collection in the left renal fossa (arrows) on ce CT images 3 days (C,D) and 6 months (E,F) after surgery

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Fig. 5: Fig. 5 Partial nephrectomy Surgical techniques (From Mu Sook Lee, AJR 2007)

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**Fig. 6:** FIG. 6 PARTIAL NEPHRECTOMY: GRANULOMAS ce-CT images of left renal cancer before and after partial nephrectomy. Postoperative granuloma at the excision site, reducing in size during follow-up

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**Fig. 7:** FIG. 7 PARTIAL NEPHRECTOMY: FAT AT THE EXCISION SITE ce-CT images of right renal cancer before and after partial nephrectomy. Pseudo-lesion characterized by low density at the parenchymal defect on CT images 6 months after surgery. MR images show fat-like pseudolesion without contrast enhancement at the excision site 12 months after surgery.

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**Fig. 8:** FIG. 8 PARTIAL NEPHRECTOMY: LINEAR OR STELLATE PARENCHIMAL SCAR MR images of multiple renal cancers before treatment. CT images after right partial nephrectomy show a low density scar, reducing in size during the follow-up, 6, 12 and 24 months after surgery.

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**Fig. 9:** FIG. 9 PARTIAL NEPHRECTOMY: PARENCHIMAL DEFECTS Preoperative CT image shows a mass in the right kidney (RCC) (red arrow). (B,C,D,E) MR images of the abdomen obtained after partial nephrectomy showed parenchimal defect on the lateral profile of the right kidney (red arrows).

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**Fig. 10:** FIG. 10 PARTIAL NEPHRECTOMY: LOCAL RECURRENCE Ce CT images of the right kidney after partial nephrectomy for papillary renal cancer: fat at the excision
site 6 months (A) and 12 months (B) after surgery. Unenhanced (C) and post contrast (D) CT images show a local recurrence (pseudonodular increase in size of the scar) at 24 months from surgery (arrows) MR images of the left kidney 12 months after partial nephrectomy for RCC: GRE T1w (E), TSE T2w (F,H) and ce GRE T1w (G) images show an enhancing mass in the perinephric space (arrows).

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**Fig. 11:** FIG. 11 PARTIAL NEPHRECTOMY: POSTOPERATIVE COMPLICATIONS (A) Preoperative CT image shows a mass in the left kidney (RCC). (B) ce-CT image obtained 3 days after surgery, demonstrates a postoperative defect in the renal parenchyma and accumulation of #uid (urine) in the perirenal space, due to a urinary leak. (C) 5 days after surgery, CT image shows reduction of the perirenal fluid collection, after placement of a ureteral stent. Resolution of the urinary leak and fluid collection in the following CT controls (D,E,F)

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**Fig. 12:** FIG. 12 PARTIAL NEPHRECTOMY: POSTOPERATIVE COMPLICATIONS
Unenhanced (A) and post contrast (B) CT images obtained 3 days after surgery show a hyperdense perinephric fluid collection, without contrast enhancement, a finding consistent with hematoma.

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**Fig. 13:** FIG. 13 RENAL CRYOABLATION (67-year-old man who underwent left renal cryoablation for renal cell carcinoma) On MR images, cryolesion was more than 1 cm larger than the original mass 24 hrs after treatment and showed progressive decrease in size at 1, 3, 6, 12, 18, 24, 36, 48, 60 and 96 months. The cryolesion showed no significant
vascularization on conventional and subtracted ce-GRE-FS-T1w images at 24hrs and 1, 3, 6, 12, 18, 24, 36, 48, 60 and 96 months after surgery.

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**Fig. 14:** FIG. 14 RENAL CRYOABLATION (67-year-old man who underwent left renal cryoablation for renal cell carcinoma) Ce-CT images obtained at 6, 12, 18, 24, 36, 48 and 60 months after surgery showed hypodensity of the treated area and progressive decrease in cryolesion size.

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**Fig. 15:** FIG. 15 RENAL CRYOABLATION: LOCAL RECURRENCE (62-year-old woman who underwent renal cryoablation for 2 papillary renal carcinomas of the left kidney) Criolesion on the lateral margin of the left kidney showed low signal intensity on TSE T2w images and progressive reduction in size 12, 24, 36 and 48 months after surgery (red arrows). Cryolesion on the upper pole of the kidney showed a local recurrence at 24 months (white arrow), treated again with cryotherapy (yellow arrow). TSE T2w MR images showed 3 metachronous nodules at 48 months (black arrows)

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**Fig. 16:** FIG. 16 RENAL CRYOABLATION: LOCAL RECURRENCE (69-year-old man who underwent renal cryoablation for renal carcinoma of the left kidney (white arrow)) MR images showed an enhancing nodule on the lateral margin of the treated area at 6 and 12 months (red arrows) after treatment

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**Fig. 17:** FIG. 17 RENAL CRYOABLATION: POSTOPERATIVE COMPLICATIONS (64-year-old man who underwent left renal cryoablation for renal cell carcinoma) MR images showed incomplete ischemia of cryolesion with small intrallesional enhancement 24 hrs after surgery, particularly on subtracted ce-GRE-FS-T1w images (red arrow), which disappeared 1 month after tretment.

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**Fig. 18:** FIG. 18 RENAL CRYOABLATION: POSTOPERATIVE COMPlications (77-year-old man who underwent left renal cryoablation for renal cell carcinoma) MR images showed perilesional haematoma 1 (red arrows) and 3 months after surgery, probably due to blood clot dissolution.

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Fig. 19: FIG. 19 RENAL RADIOFREQUENCY ABLATION: MR MR images show a metachronous nodule in the left kidney in patient treated with cryoablation for papillary renal carcinoma (arrows). After RF ablation, the treated area appears hypointense on T2w images, without any enhancement after contrast medium infusion and reducing in size.

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**Fig. 20:** FIG. 20 RENAL RADIOFREQUENCY ABLATION: CT MR images show an enhancing nodule in the right kidney (arrows) in patient previous treated with left nephrectomy for papillary renal carcinoma. 3 months after RF ablation, the treated area appears heterogeneously hypodense compared to renal parenchima, without any enhancement after contrast medium (arrows). 6 months after treatment MR images show lack of enhancement and reduction in size of the treated area (arrows).

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Fig. 21: FIG. 21 RENAL RADIOFREQUENCY ABLATION: RECURRENCE Ce-CT images obtained 3 months after RF ablation show incomplete lack of enhancement in the lateral portion of the ablation zone in the right kidney (arrows). MR imaging follow-up performed 6 months after treatment shows an increase in size of the treated area, with a nodular enhancing component, consistent with recurrence (arrows).

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Conclusion

DISCUSSION

The most important parameters in the CT/MR imaging evaluation of patients treated with total nephrectomy for renal tumors are the absence of enhancing nodules at the excision site and at the perinephric space.

The most important parameters in the evaluation of conservative treated kidneys were the lack of increase in size and the hypovascularization of the treated areas.

The most frequent post operative complications were haematomas, fluid collections and collecting system fistulas.

Most frequent patterns of local recurrence were increase in size and vascularization of the scar. Subtraction (MR) or quantitative assessment using ROIs (CT) must be used to evaluate contrast enhancement.

The most effective imaging techniques were multiphasic acquisition (CT) and morphologic TSE T2w and dynamic ce-FS-GRE T1w sequences before and after digital subtraction technique (MR).

CONCLUSION

CT and MR were effective imaging techniques in the immediate, short and long-term follow-up of the kidney following various kidney-directed terapies.
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