Wilms Tumor: Imaging of Pediatric Renal Masses

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What is Wilms Tumor?

~defining features~

- First classified as an embryonal sarcoma by Max Wilms in 1899 at the Institute of Pathology in Bonn, Germany.

- Also known as *nephroblastoma*, it is the most common solid renal tumor of childhood.

- Usually bulky, may arise in any portion of the kidney, and expands within the renal parenchyma to displace and distort the pelvicalyceal system.

- Distinguished by vascular invasion and displacement of surrounding structures.
~ Epidemiology ~

- Accounts for roughly 5% of childhood cancers and 87% of pediatric renal masses.
- Incidence = 1:10,000. Approximately 500 new cases annually.
- Peak incidence = 3-4 years of age (80% present before age 5).
- 5-10% present with bilateral Wilms.
- National Wilms Tumor Study (NWTS) - has 85% of all new cases diagnosed in North America enrolled in group protocols.
Associated Syndromes
~ the minority of cases~

- **WAGR Syndrome**
- **Drash Syndrome** – male pseudo-hermaphroditism, progressive glomerulonephritis
- **Overgrowth Syndromes** – Beckwith Wiedemann, hemihypertrophy.
- **GU abnormalities** – hypospadias, cryptorchidism, horseshoe kidney.

Patients with associated syndromes should be screened starting at 6 months of age, with initial CT and follow up US every 3 months up to 7 years of age.
~ Pathogenesis of Wilms tumor ~

■ Wilms is an abnormal embryonal renal neoplasm, presumed to develop from abnormal histiogenesis. 
  ➞ Precursor cells = renal blastemal tissue 
  (nephrogenic rests)

■ Normal nephrogenesis is complete at 36 weeks gestation. Kidneys of normal full-term newborns contain no foci of renal blastema.

■ Wilms is thought to arise from metanephric precursor tissue that persists in the developing child.
~Nephrogenesis~

- Ureteric buds penetrate metanephric tissue that is molded around the distal ends like a cap. Buds gives rise to collecting system (ureter, calyces, renal pelvis).

- Epithelium of the ureteric bud from the MESONEPHROS interacts with mesenchyme of METANEPHRIC blastema.

- Metanephric blastemal tissue expresses WT1 (transcription factor) which enables metanephric tissue to respond to induction by ureteric buds. Nephrons are formed from metanephros through molecular signaling.
**Gross Pathology**

- Solid multi-lobulated, gray/tan intrarenal mass with a pseudocapsule distorting the renal parenchyma and collecting system. Spreads by direct extension but does not encase the aorta.

**Histology**

*most important prognostic factor*

- Usually shows well-differentiated renal tissue with embryonic glomeruli and tubule formation surrounded by spindle cell stroma. **Triphasic pattern = stromal, blastemal and tubular elements.**

- 10% of Wilms tumors have unfavorable histology with anaplasia (atypical mitoses or hyperchromatic cells with large nuclei).

~ Renal Anatomy ~

Positions of Urinary Organs

- Renal artery
- Renal vein
- Fibrous capsule
- Cortex
- Medulla
- Renal calyx
- Renal pelvis

Left kidney and suprarenal gland in situ


Gray’s Anatomy Online
Anatomy
~Axial View~

Stomach
Pancreas
Renal Vein
Abdominal Aorta
Kidney

http://radiology.med.sc.edu/%20Portalveinliver.htm

Clinical Presentation of Wilms tumor

- **Common**: Patient presents with an asymptomatic abdominal mass noted by patient, physician or parent.
- **Uncommon**: Patient can present with abdominal pain, anorexia, hematuria and hypertension due to renin production by tumor.
- **Rare**: Patient presents with dysuria and renal failure.

* Discovered after coincidental trauma in up to 10% of cases.
Index Patient

- KG is a 2 ½ year-old girl who presented in January 2006 with left upper quadrant pain and a left flank mass detected by her parents.
- She underwent CT scan directly, which showed....
MDCT Abdomen with Oral & Intravenous Contrast

…a very large multi-lobulated, heterogenously enhancing mass replacing the pole of the left kidney. *CLAW SIGN*

- The mass shows smooth margins. It measured 12 x 7 cm in its largest dimension and extended from approximately the iliac crest up to the diaphragm.
- The lesion itself appears to be comprised of either multiple confluent masses, or single large septated mass.
- It is exerting mass effect on the surrounding abdominal structures pushing the pancreatic tail and splenic vein, and the stomach superiorly and anteriorly.
- The left renal artery and vein are widely patent.
Coronal and Sagittal Reconstructions

Tumor Mass – heterogeneous, “claw” formation.
Differential diagnosis of a Renal Mass

*varies depending on clinical presentation + imaging features*

- Malignant renal mass –
  - Clear Cell Sarcoma
  - Leukemia; Lymphoma
  - Metastasis (e.g. neuroblastoma)
  - *Renal Cell CA*
  - Rhabdoid tumor; rhabdomyosarcoma
  - Wilms tumor

* Far more common in older age groups.*
## KG’s differential

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<th>Renal Mass</th>
<th>Clinical and imaging features</th>
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<td>Wilm’s Tumor</td>
<td>Large solid mass, often with vascular invasion. Most common solid renal mass of childhood.</td>
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<tr>
<td>Congenital Mesoblastic Nephroma</td>
<td>Most common solid renal mass in newborns and infants. Tends to be a large infiltrative mass with ill-defined margins and no capsule.</td>
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<tr>
<td>Multilocular Cystic Nephroma</td>
<td>Multicystic mass with little solid tissue. Septa are the only solid components – distinguished from Wilms by absence of expansile solid masses.</td>
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<tr>
<td>Rhabdoid Tumor</td>
<td>Rare, highly aggressive. Imaging features can closely resemble Wilms. Usually diagnosed in infancy. Associated with brain malignancies.</td>
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March, 2006
Diagnostic Imaging of suspected Wilms Tumor: low performance modalities ~Plain film, IVU~

*Common imaging challenge = stating the renal origin of the mass.*

No longer commonly used:
- Plain film – minimal contribution; may show typical changes of ribs caused by compression by a slowly growing tumor. (Modality of choice to evaluate for presence of lung mets.)
- IVU – shows distortion of the pyelocaliceal system – not sufficient for diagnosis and staging and now rarely performed.

Diagnostic Imaging of Suspected Wilms Tumor: high performance modalities

US, CT, MR

- **US** – Demonstrates intrarenal mass with heterogeneous echogenicity. Bursts the normal kidney with a spur of normal parenchyma surrounding the tumor.
  - Color Doppler Study – may help to better define and depict tumor extent and necrotic area, as well as vascular invasion.

- **CT** – Demonstrates heterogeneous mass with slightly lower attenuation than normal kidney. Allows exam of contralateral kidney.
  - IV contrast – mandatory. Shows nodal, hepatic mets, and tumor extension into renal vein or IVC.

- **MRI** – Heterogeneously hypointense on T1, hypo/iso. intense on T2. Most sensitive modality for determination of caval patentcy. [requires sedation – not routinely done]

Back to KG...

- KG underwent left nephroureterectomy and adrenalectomy with complete resection of tumor.
- Pathology showed multifocal Wilms tumor with diffuse anaplasia, intact renal capsule, and focal invasion of renal sinus and renal sinus vessels. Multiple nephrogenic rests were present. Resected lymph nodes were negative for tumor involvement.
- There was no evidence of right kidney involvement or abdominal lymph node disease in preoperative scans. Chest CT was negative for metastases.
**Staging**

- **Staging of Wilms Tumor: by imaging, surgery, and pathology**

- **Stage**
  - **I**
    - Description: Limited to the kidney and completely resectable with renal capsule intact; renal sinus may be infiltrated but not beyond hilum.
  - **II**
    - Description: Tumor infiltrates beyond kidney but completely resected.
  - **III**
    - Description: Residual tumor confined to abdomen and without hematogenous spread.
  - **IV**
    - Description: Hematogenous metastases to lung (most common), bone, liver or brain.
  - **V**
    - Description: Bilateral renal involvement; each side staged separately.
KG was found to have Stage II anaplastic Wilms Tumor

*Most recent trial showed that stage II disease did not have a worse prognosis with diffuse anaplasia than without.

Gross Pathology shows multilobular encapsulated tumor, originating from the kidney.

Multifocal disease shows hyperchromatic cells with atypical mitoses and large nuclei. Each focus is at a slightly different stage of disease.

Courtesy of Dr. Mara Barth, Boston Children’s Hospital
Prognosis

- 5 year survival rates, based on recent studies:
  - Favorable histology – survival approaches 90%
  - Most important negative prognostic factors are unfavorable histologic subtypes.
  - Recent NWTS data suggests 3-year survival rates for bilateral Wilms tumors = 82%
KG – multi-modal treatment

*Based on data from National Wilms Tumor Study Trials

- **Surgery:** Radical nephrectomy via transabdominal incision is procedure of choice with biopsy of regional lymphatics and careful examination of opposite kidney for staging and prognosis. Major emphasis placed on avoiding spillage of tumor as this increases abdominal recurrence.

- **Chemotherapy:** Adjuvant therapy planned based on staging. Current studies are focusing on minimizing toxicity of therapy.

- **Radiation:** Complicated by potential for growth disturbance and organ toxicities. Only used for patients with III or IV unless unfavorable histology seen.

- **Follow-up imaging:** Ultrasound

Based on the anaplastic features of her Stage II tumor, KG is currently undergoing chemotherapy and radiation.
Companion Case
~ Patient # 2 ~

- JC is a 7 year old boy, s/p resection for stage III Wilms tumor who presents for restaging due to recurrence of palpable abdominal mass.
JC’s preoperative CT Scan: dated April, 2005

- CT abdomen with contrast: shows heterogeneously enhancing solid mass arising from the left kidney with adjacent soft tissue, probably lymphadenopathy, and thrombus in the left renal vein.

- Venous extension of Wilms tumor follows the “rule of 10’s”: 10% extend into renal vein; 10% of that group extend into IVC; 10% of the latter further extend into the right atrium.

Courtesy of Dr. Melissa Gerlach, Boston Children’s Hospital
Restaging October 2005: status post Wilms resection
~Abdomen, Pelvis CT with contrast~

- The left kidney is absent.
- There is a lobulated soft tissue mass in the left renal fossa and lower retroperitoneum associated with multiple vascular clips. It is bilobed with a large mass at the level of the SMA and another at the level of the IMA. The lower component demonstrates cystic degeneration in its inferior and lateral aspects.
Multiple poorly enhancing masses seen throughout the lungs. Largest in the anterior aspect of the apical posterior segment of the left upper lobe, measures approximately 3.0 x 1.8 cm.

Left upper mediastinal adenopathy.

Given the lung findings suggestive of hematogenous spread, JC likely has Stage IV disease.
Potential diagnostic confusion
~ Patient #3 ~

KO is a 5-year-old girl from Puerto Rico, who presented to her physician last November with a reactive airway disease exacerbation. On chest X-ray, an incidental calcified right upper quadrant mass was discovered.
- Biopsy was performed and preliminary pathology was consistent with ganglioneuroma.
- Due to size of the mass…KO was referred to Boston for repeat metastatic workup and resection of the mass.
~Abdominal CT with contrast~

From OSH

- Show large right-sided adrenal mass with coarse central calcifications. Similar sized mass was seen in the left adrenal.
- Complete encasement of the IVC and partial encasement of the left renal vein and SMA were noted.
Final diagnosis s/p resection: Neuroblastoma

- Pathologically distinct from Wilms tumor – but frequently presents in the abdomen as a mass arising from adrenal glands or paraspinal ganglion.
- 2nd most common abdominal malignancy in children – occurring as frequently as Wilms.
- Radiographically indistinguishable from Wilms tumors.
- Features that aid in diagnosis:
  - Neuroblastomas usually cross the midline whereas Wilms is confined to one side.
  - Neuroblastomas may cause an outward and downward displacement of the kidney (drooping lily) whereas Wilms tumors are intrarenal masses, rarely causing a change in axis of the kidney.
  - Neuroblastomas are more likely to present with mets, and tend to calcify at higher frequency. Tumor markers include VMA and other catecholamines.
Wilms Tumor vs. Neuroblastoma
~Axial CT~

Contrast-enhanced axial scan at the level of the renal hilum: Large, well-defined tumor seen on the right attenuates similarly to the renal parenchyma which displaces the right kidney (double arrow) medially.

Contrast-enhanced axial scan at the level of the upper pole of the kidneys: Large, irregularly-calcified tumor seen in the retroperitoneum, displacing left kidney dorsally (double arrow).

http://www.szote.u-szeged.hu/radio/a13.htm
Review – take home points

- Wilms is an embryonal renal neoplasm accounting for greatest percentage of pediatric renal masses (peak age 3-4). Can be difficult to distinguish radiographically from other renal masses & neuroblastoma.

- Diagnosis of a renal mass is made by confronting elements of clinical presentation with imaging – definitive diagnosis often awaits path.

- Steps in diagnosis: radiologist localizes mass, analyses tumor features, searches for regional/distant spread.

- High performance imaging modalities commonly used:
  - US
  - CT
  - MR
Review – imaging of Wilms

- **US** – 1st imaging test for Wilms tumor – excellent for depicting the mass, identifying adjacent organ invasion and tumor thrombus extension in renal vein and IVC.

- **CT (contrast & non-contrast)** – Preferred modality for further staging and cross-sectional imaging – enables eval. of lung mets and view of both kidneys. Controversy surrounding use of lung CT vs. plain film for mets. at initial diagnosis.

- **MR** – Similar imaging benefit to CT. Most sensitive modality for determination of caval patentcy, but requires sedation.
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References