Congenital anomalies of the kidney and urinary tract in adults: Value of 64-slice multidetector

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Learning objectives

To review, illustrate and discuss the value of 64-slice multidetector CT (MDCT) in evaluating congenital anomalies of the kidney and urinary tract (CAKUT) in the adult population.
Background

CAKUT result from failure of normal nephron development of the urinary collecting system. Although these anomalies may become apparent in childhood, many of these malformations remain silent until incidental detection during the evaluation of treatment of other pathologies detected in adulthood. In addition, CAKUT may also cause or associate with various urologic symptoms and complications in this age group.
MDCT can accurately show CAKUT, help assess their clinical relevance, and depict associated malformations or complications. The added value of CT-angiography, CT-urography, and volume rendering has proved useful in this clinical setting, by providing optimal display of anatomical details and pathological processes. The advantage of MDCT urography derives from its ability to depict normal urinary tract anatomy, including the renal parenchyma and collecting structures and ureters. Most frequent congenital anomalies of the upper urinary system:

<table>
<thead>
<tr>
<th>Kidney</th>
<th>Pyelocalyceal system and ureter</th>
<th>Renal vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agenesis</td>
<td>Extrarenal pelvis</td>
<td>Retroaortic left renal vein</td>
</tr>
<tr>
<td>Malrotated</td>
<td>Duplicated pyelocalyceal system</td>
<td>Accessory renal artery</td>
</tr>
<tr>
<td>Hypoplasia</td>
<td>Pyeocalyceal diverticulum</td>
<td>Early bifurcation of renal artery</td>
</tr>
<tr>
<td>Ectopic</td>
<td>Congenital megacalyx</td>
<td>Renal artery entrapment by diaphragmatic crux</td>
</tr>
<tr>
<td>Fused</td>
<td>Ureteropelvic junction stenosis</td>
<td></td>
</tr>
<tr>
<td>Fetal renal lobulation</td>
<td>Megaureter</td>
<td></td>
</tr>
<tr>
<td>Congenital cystic disease</td>
<td>Ureterocele</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ureter retrocava</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vesicoureteral reflux</td>
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</tbody>
</table>

Congenital anomalies of renal number (Figs. 1 on page 7 and 2 on page 7), size (Figs. 3 on page 8 and 4 on page 9), orientation (Figs. 5 on page 10, 6 on page 11, 7 on page 12 and 8 on page 13), position (Figs. 9 on page 14 and 10 on page 15), and shape (Fig. 11 on page 16) are easily depicted with MDCT urography. Three-dimensional reformatted images can provide good delineation of congenital fusion anomalies of the kidney (Fig. 12 on page 17).

Anomalies of the collecting system are better depicted with MDCT urography. Renal pelvic and ureteral abnormalities are detected on axial images, but they can be optimally depicted in 3D reformations (Figs. 13 on page 18, 14 on page 19, 15 on page 20 and 16 on page 21), particularly when the lumen has been previously opacified (Figs. 17 on page 22 and 18 on page 23). Urethral masses and filling defects can be
seen on both axial images and tridimensional reformations, but concentric urethral wall thickening is usually not seen 3D displays.

MDCT angiography is also an optimal modality for non-invasive assessment of many vascular territories, with similar sensitivity and specificity than conventional angiography. MDCT angiography may be used for evaluating the main renal artery, their pedicle, and their branches.

Maximum-intensity projections (MIP) are the technique of choice for evaluating the renal vascular supply, providing angiography-like images that can discriminate between vessel lumen, normal vessel wall and mural calcification. Even small vessel are well depicted as long as they have a higher CT number than the surrounding tissue.

Congenital variants or anomalies of the vascular supply include accessory renal arteries (the most common renal vascular variant), early bifurcation of renal artery, and retroaortic or circum-aortic left renal vein (Fig. 19 on page 24). Accessory renal arteries usually originate from the abdominal aorta. They are classified as polar (Figs. 20 on page 25, 21 on page 26 and 22 on page 27) or hilar (Fig. 23 on page 28). The main renal arteries divide into anterior and posterior branches at the renal pelvis. The prehilar branching of the renal artery is a frequent variant which differs from accessory renal arteries (Figs. 24 on page 29 and 25 on page 30).

Conventional angiography is a suboptimal modality for evaluating extrinsic compressions of the renal arteries. In this regard, MDCT angiography has proved useful in the evaluation of both intrinsic vascular abnormalities and extrinsic vascular compressions (Fig. 26 on page 31).

MDCT cystography is progressively replacing conventional cystography in the evaluation of patients with suspected bladder rupture in most trauma centers. Also, CT cystography provides information regarding bladder morphology, wall structure, vesico-ureteric junction, and congenital anomalies of the bladder (Figs. 27 on page 32). Most frequent congenital anomalies of the lower urinary system:

<table>
<thead>
<tr>
<th>Bladder</th>
<th>Urethra</th>
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<tbody>
<tr>
<td>Congenital bladder diverticula</td>
<td>Posterior urethral valve</td>
</tr>
<tr>
<td>Urachal sinus</td>
<td>Prune-Belly syndrome</td>
</tr>
<tr>
<td>Urachal diverticulum</td>
<td>Congenital urethral stricture</td>
</tr>
<tr>
<td>Urachal cyst</td>
<td>Congenital urethral polyps</td>
</tr>
</tbody>
</table>
Retrograde urethrography and conventional cystourethroscopy are classical methods for evaluating the urethra and their structural problems or injuries. CT voiding urethrography and CT virtual urethroscopy are promising imaging tools that may become relevant in a near future (Fig. 28 on page 33).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
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<tbody>
<tr>
<td>Patent urachus</td>
<td>Mullerian duct remnants: enlarged prostatic utricle and Mullerian duct cyst</td>
</tr>
<tr>
<td>Vesicourachal diverticulum</td>
<td>Cowper's syringocele</td>
</tr>
<tr>
<td>Bladder ears</td>
<td>Anterior urethral valves and diverticula</td>
</tr>
<tr>
<td>Bladder agenesis</td>
<td>Megalourethra</td>
</tr>
<tr>
<td>Megacystitis</td>
<td>Urethral duplication</td>
</tr>
<tr>
<td>Bladder duplication</td>
<td>Congenital urethroperineal fistula</td>
</tr>
<tr>
<td>Bladder septation</td>
<td>Anorectal malformations</td>
</tr>
<tr>
<td>Exstrophy of the bladder</td>
<td></td>
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</tbody>
</table>
Fig. 0: Renal agenesis. Coronal maximum intensity projection (a) and volume rendering (b) show a unilateral renal agenesis. Both the right kidney and the right renal artery were absent.

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**Fig. 0**: Renal agenesis. Coronal maximum intensity projection (a) and volume rendering (b) demonstrate absence of the left kidney and compensatory hypertrophy of the right kidney, which shows a cortical cyst. The left main renal artery was absent.

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Fig. 0: Hypoplastic functional kidney. Axial (a) and coronal (b) maximum intensity projections, and volume rendering (c) show a right hypoplastic functional kidney and a hypertrophied left kidney with incompletely duplicated pyelocalyceal system.

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**Fig. 0:** Hypoplastic non-functional kidney. Axial contrast-enhanced MDCT image (a) and coronal maximum intensity projection (b) show a left hypoplastic non-functional kidney (arrow) and a hypertrophied right kidney.

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**Fig. 0:** Malrotated kidney about the horizontal axis. Axial contrast-enhanced MDCT image (a) and volumen renderings (b, c) show a malrotated right kidney about the horizontal axis, with a medially located pelvis.

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Fig. 0: Anterior malrotated kidney. Axial (a) and sagittal (b) contrast-enhanced MDCT images show an anterior malrotated left kidney with pyelocaliceal stones. Volume rendering (c) shows stones in anteriorly oriented renal pelvis.

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**Fig. 0:** Lateral malrotated kidney. Axial maximum intensity projection (a) and volumen rendering (b) show a lateral malrotated right kidney. The renal pelvis shows abnormally lateral location.

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**Fig. 0:** Horseshoe kidney with anteriorly oriented renal pelvis. Axial contrast-enhanced MDCT image (a) shows a horseshoe. The renal isthmus is found anterior to the great retroperitoneal vessels. Corresponding volumen rendering (b) better show the inferior renal istmus, the normal renal arteries, and the anterior location of the renal pelvises.

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**Fig. 0:** Ectopic pelvic kidney. Volume rendering (a) demonstrates absence of the left kidney at the left renal fossa. Instead, an ectopic left pelvic kidney is seen. The axial contrast-enhanced MDCT image (b) shows an engorged left iliac vein (asterisk), due to left aberrant renal vein (not shown). The ectopic kidney receives blood supply from two renal arteries arising form the aorta (arrowhead) and left iliac artery (arrow).

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**Fig. 0:** Ectopic pelvic kidney. Coronal contrast-enhanced MDCT image (a) and volumen rendering (b) show an ectopic right pelvic kidney.

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Fig. 0: Fetal renal lobulation. Coronal maximum intensity projections (a, b) show persistent fetal lobulation in both kidneys.

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**Fig. 0:** Crossed-fused ectopic kidney. Axial maximum intensity projection (a) and volumen rendering (b) show crossed fused renal ectopia. Right kidney crosses to the left and converge with the lower pole of the left orthotopic kidney.

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**Fig. 0:** Ureteropelvic junction stenosis. Coronal maximum intensity projections (a, b) show left ureteropelvic junction stenosis, close to crossing vessels of uncertain involvement (arrow). Pyelocalycial dilatation and decreased cortical nephrogram are seen.

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**Fig. 0:** Ectopic megaureter. Sagittal contrast-enhanced MDCT image (a) shows a hypoplastic left kidney and a dilated left ureter. Axial contrast-enhanced MDCT image (b) shows dilatation of the distal urether, draining into the prostate gland. Sagittal (c) and axial (d) T2-weighted MR images show confirm CT-based diagnosis.

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**Fig. 0:** Ectopic megaureter. Axial image (a) shows a dilated left seminal vesicle (asterisk). Coronal multiplanar projection image (b) shows hypoplastic non-functional left kidney with distal dilated ureter (arrow) which ends into left seminal vesicle (asterisk).

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**Fig. 0:** Ectopic megaureter. Sagittal contrast-enhanced MDCT image (a) shows dilatation of the right urether (arrows). Coronal (b) and axial (c) contrast-enhanced MDCT images show dilatation of the right distal urether, which apparently drains into the vagina. The contrast-enhanced urethra (arrowhead) is found anterior to the vagina and ectopic urether.

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Fig. 0: Duplicated collecting system. Coronal maximum intensity projection (a) and volumen rendering (b) show an incompletely duplicated left pyelocalyceal system and ureter. The left ureters converge and fuse near the bladder.

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**Fig. 0:** Ureterocele. Coronal curved (a) and axial (b) contrast-enhanced MDCT images show distal ureter balloons at its opening into the bladder, forming a sac-like pouch.

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Fig. 0: Circumaortic left renal vein. Axial (a, b) and coronal (c) maximum intensity projections show a circumaortic left renal vein with preaortic (arrowhead) and retroaortic (arrow) components.

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Fig. 0: Accessory polar renal arteries and early branching of main arteries (same patient). Coronal volume rendering (a) and axial maximum intensity projection (b) show an accessory right renal artery (arrowhead) that supplies the superior pole of the right kidney, and early (prehilar) branching of both main renal arteries.

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**Fig. 0:** Accessory polar renal arteries and early branching of main artery. Coronal (a) and axial (b) maximum intensity projections show an accessory left renal artery (arrowhead) that supplies the inferior pole of the left kidney, and early (prehilar) branching of the right main renal artery. See also bilateral polycystic kidneys.

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**Fig. 0:** Horseshoe kidney and accessory polar renal artery. Coronal maximum intensity projection (a) and volume rendering (b) show horseshoe kidneys with one accessory renal artery (arrowhead) originating from right iliac artery and supplying the inferior pole of the right hemi-kidney.

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Fig. 0: Accessory hilar renal artery. Coronal maximum intensity projection (a) and volume rendering (b) show an accessory right hilar renal artery.

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**Fig. 0:** Accessory polar renal artery and early branching of main arteries. Coronal maximum intensity projection (a) and volume rendering (b) show an accessory right renal artery that supplies the superior pole of the right kidney, and early (prehilar) branching of both main renal arteries.

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Fig. 0: Accessory polar renal arteries and early branching of main arteries. Coronal maximum intensity projection (a) and volume rendering (b) show an accessory left renal artery that supplies the inferior pole of the left kidney, and early (prehilar) branching of the both main renal arteries.

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**Fig. 0:** Renal artery stenosis caused by the diaphragmatic crura. Axial (a) and coronal (b) maximum intensity projections, and volume rendering (c) show a high-grade stenosis at the proximal segment of the right renal artery, caused by entrapment of the diaphragmatic crura (arrow). Entrapment of the celiac trunk was also found, and collateral circulation through the gastroduodenal arcade was seen (d).

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**Fig. 0:** Urachal remnant. Sagittal contrast-enhanced MDCT image shows an urachal remnant (arrows), travelling from the anterior-superior aspect of the bladder into the umbilical region.

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Fig. 0: Infected Cowper’s syringocele. Axial (a) and sagittal (b) contrast-enhanced MDCT images show an encapsulated fluid collection below the bulbar urethra, consistent with periurethral abscess in a patient with known Cowper's syringocele.

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Conclusion

The increased speed and definition of 64-slice multidetector CT equipments provide high-quality images with submilimetric and isotropic 3D voxels, and optimal three-dimensional renderings, which are particularly suitable for a comprehensive anatomic evaluation of the urinary system and their most common congenital anomalies.
References


