ISMRM 2010 syllabus

Assessment of renal function in children

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Functional MRI is now challenging scintigraphy techniques in the routine assessment of pediatric kidney pathologies. Unlike scintigraphy, MRI can provide both anatomic information and functional analysis without any radiation exposure. The most common indication for MR Urography (MRU) in children is the exploration of hydronephrosis. In this setting, MRI has gained popularity since the functional analysis can be performed separately on the upper and lower poles of duplicated systems. This is not possible in diuretic renal scintigraphy (^{99m}Tc-MAG3) because of inadequate spatial resolution. An MRU for hydronephrosis usually takes less than 30 minutes to acquire but requires a dedicated post-processing package (1-3).

1 - Dynamic contrast-enhanced (DCE) imaging

DCE imaging is the most widespread technique used to assess kidney function in clinical practice. However the risk of nephrogenic systemic fibrosis posed by gadolinium-based contrast agents (GBCA) should always be considered. Recent recommendations (4) from the European Society of Paediatric Radiology (ESPR) stipulate that children with kidney disease should be injected only with macrocyclic GBCA. If the GFR is below 30 mL/min/, a risk-benefit analysis regarding the use of contrast-enhanced MRI should be conducted in consultation with the attending nephrologist.

The renography sequence is usually a 3D T1-weighted fast gradient echo sequence. A saturation- or inversion-recovery preparation is often included to increase T1 contrast. Since GBCA are filtered by the kidneys and not reabsorbed, they become highly concentrated in the tubules. Hence a low dose of gadolinium (<0.1 mmol/kg) is typically used to avoid T2* effects. Low doses also ensure that the relationship between signal intensity and contrast agent concentration is more nearly linear. Reported gadolinium doses range from 0.025 mmol/kg to 0.1 mmol/kg, but the difficult handling of tiny volumes in infants may lead to use 0.05 mmol/kg or more.

1.1. Split renal function (SRF) assessment:

Split renal function refers to the percentage contribution of each kidney to the total GFR. The function of the parenchyma in a region of interest is usually assessed by evaluating the area under the time-intensity curve or by applying the bi-compartmental Rutland-Patlak model, which considers a unilateral flow of tracer from the first compartment (vasculature) into the second compartment (nephrons). Results from these approaches are usually weighted by the kidney volumes.

1.2 Glomerular filtration rate (GFR)

The goal is to provide a single kidney GFR (SKGFR) in mL/min for each kidney. The signal intensities are first converted into T1 values and then into gadolinium concentrations. This promising approach has been studied both in adults and in children, but is not as reliable as reference techniques such as inulin clearance or radionuclide clearance measurements. The most sophisticated models analyze the signal from cortex and medulla separately. However, this kind of analysis is particularly challenging in hydronephrotic kidneys, due to difficulties in segmentation. The small parenchyma volume of young children is often stretched and/or atrophic resulting in only a thin rim of tissue. Differentiating cortex from medulla may therefore not be feasible in severe hydronephrosis. The Rutland-Patlak model has been the most studied in this setting, but has not been validated.

1.3. Tubular function

Some more sophisticated multi-compartment models include tubular transit times. This parameter is promising but still needs to be validated.

1.4. Obstruction

Obstruction is defined as a dilatation that will cause deterioration of kidney function if left untreated. It should be noted, however, that dilatation does not always imply obstruction, and can be a protective process. Drawing a ROI on the pelvis (either including or excluding the renal parenchyma) and plotting the mean signal intensity as a function of time provides an "excretory renogram". Typical patterns of MR excretory renograms have been adapted from O'Reilly's classification in scintigraphy. Transit times (renal transit time and caliceal transit times) have also been proposed as a means to diagnose obstruction. Both excretory renograms and renal transit times can reliably classify normal drainage, but seem to be unable to differentiate dilatation with obstruction from dilatation without obstruction (stasis). Considering this lack of specificity, a reliable kidney (glomerular) function assessment is mandatory.

2. Non-enhanced techniques.

Recent studies have focused on:

- BOLD (Blood Oxygen Level Dependent) imaging: can provide information about the oxygenation levels of cortex and medulla, from which conclusions can be drawn about oxygen consumption and kidney function. It has been shown that increased oxygenation occurs in the renal cortex and medulla with acute obstruction, suggesting reduced function of the affected kidney.
- Diffusion: a positive correlation has been reported between ADC values and SRF in hydronephrotic patients.
- Arterial spin labeling (ASL): blood is tagged and used as an endogenous contrast agent. Perfusion can be evaluated semi-quantitatively, and several teams are currently validating absolute measurement of renal plasma flow. It may help to establish a diagnosis for impaired renal function even in the absence of renal artery stenosis.

References

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