SYLLABUS

Measurement of Renal Perfusion and Filtration

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Teaching Session: Functional kidney imaging with MRI (adv.)

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https://github.com/arvidl/functional-kidney-imaging

Abstract

Kidney function is related to maintenance of fluids, electrolytes, acid-base balance and clearance of toxins. Normal kidney function is maintained by coordinated regulation at different levels of organization warranting an integrative approach to kidney function in health and disease.

Important parameters describing kidney physiology and function are: **renal plasma flow**, RPF = (1 - Hct) · RBF, where Hct (hematocrit) is the fraction of blood volume representing the cellular elements of blood, RBF is the volume of blood delivered to the kidneys per unit time [mL/min]; **renal perfusion**, denoting renal blood flow per unit volume of kidney [mL/min/100 mL]; and **glomerular filtration rate**, GFR, the volume of fluid filtered from the renal glomerular capillaries into Bowman's capsule per unit time, equal to the sum of the filtration rates of all functioning nephrons [mL/min]. Typical values in healthy humans: Hct $\sim$0.40, RPF $\sim$600 mL/min, GFR $\sim$125 mL/min (70-kg man, where population studies have shown GFR to be proportional to body surface area, and sex and age dependent).

This teaching session will introduce measurement of renal perfusion and filtration in the framework of **imaging-based biomarkers** and **computational medicine / systems medicine**.

(**i**) The first part will give a brief overview of kidney structure and function and the key physiological parameters relevant to the clinics. In particular, we describe the gross functional anatomy of the kidney, the renal blood supply, and the ultrastructure of the filtration barrier, as well as some major diseases and conditions affecting normal perfusion and filtration. To complete this motivational part, we mention assessment of kidney function in the clinical laboratory based on the measurement of the clearance of various substances (exogenous and endogenous markers) by the kidneys, incorporating the '**conservation of mass**' principle also underlying imaging-based modeling of renal perfusion and filtration.

(**ii**) The second part addresses MR acquisition techniques in use for measuring perfusion and filtration, with a focus on DCE-MRI.

(**iii**) This part presents **tracer kinetics** and **compartment models** applied to parenchymal regions down to single voxels, where **motion correction** can be an issue.

(**iv**) In the fourth part, model-based estimation of renal perfusion and filtration using different numerical **software** and programming languages will be demonstrated.

Finally, we will point to relevant literature, software tools, and new initiatives addressing the lack of standardization in acquisition and analysis methods, limited access to data from previous studies, and the challenges of **reproducibility** and **validation**.

Extended list of bibliographical references:

Kidney function :
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29]

Computational physiology / medicine :
[30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46]

Imaging-based biomarkers :
[47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74]

DCE-MRI :
[75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97]

BOLD fMRI :
[98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125]

Tracer kinetics & compartment modeling :
[126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150]

Motion correction :
[151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166]

Kidney segmentation :
[167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185]

Validation, accuracy & reproducibility :
[186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 114, 200, 201, 202, 203, 204]

Software tools (DCE-MRI, visual analytics) :
[205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219]

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