Multiparametric T1, T2 and T2* MR Imaging

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Disclosure

- Neither I nor my immediate family members have a financial relationship with a commercial organization that may have a direct or indirect interest in the content.
Objectives

- Describe the basic techniques of myocardial MR mapping
- Explain the role of myocardial MR mapping
- Identify findings of common diseases on T1, T2, and T2* maps
Cardiac MRI

- Important role in the assessment of anatomy, function and tissue characterization
- Traditionally qualitative characterization of the myocardium
- LGE may not identify diffuse fibrosis if contrast uptake is uniform
All tissues have inherent T1 relaxation times

Key source of soft tissue contrast

Myocardial diseases can alter native T1 and T2 signals
Different acquisition schemes to sample the T1 recovery signal:

- MOLLI
- ShMOLLI
- SASHA
- SAPPHIRE
Inversion Recovery Techniques

- MOLLI, shMOLLI, variants
- Potential bias from T2 and magnetization transfer effects due to SSFP readout
  - Heart rate dependence
  - High precision
  - T1 values tend to be lower than SR-based techniques

Saturation Recovery Techniques

- **SASHA**
  - More accurate
  - Lower precision
  - Similar reproducibility

Variation in T1 Mapping Values

- **Scanner related:**
  - Magnetic field strength
  - Image acquisition plane
  - Region of myocardium being sampled
  - Type of mapping sequence

- **Patient related:**
  - Heart rate, age, and sex

Non-Contrast (Native) T1 Mapping

Normal myocardium has a T1 relaxation time of ~950-1050 ms at 1.5T and ~1100-1150 ms at 3T.

Post-Contrast T1 Mapping

Administration of contrast shortens the T1 relaxation time of myocardium by several hundred milliseconds

Extra-Cellular Volume Fraction (ECV)

Proportion of extracellular space within the myocardium

Normal myocardial ECV ~24-30%

Extra-Cellular Volume Fraction (ECV)

- Calculated on the basis of non-enhanced and contrast-enhanced T1 values with hematocrit:

\[
ECV = \frac{1/T1_{MYO-POST} - 1/T1_{MYO-PRE}}{1/T1_{BP-POST} - 1/T1_{BP-PRE}} \times (100 - \text{hematocrit})
\]

T2 Imaging

T2 relaxation time is altered by the water content in tissue
T2 Mapping

T2 maps are generated on the basis of a similar principle to that used in T1 mapping.

Normal myocardial T2 values 45-55 ms
**T2* Imaging**

- Clinical standard for assessment of myocardial iron
- $T2^*$ shorter than $T2$
- $T2^*$ decay progresses with time

Anderson LJ et al. Eur Heart J 2001; Chavan GB et al. Radiographics 2009
T2* Imaging

- T2* post-processing is typically performed off-line
- T2* maps can be generated at the scanner

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FIBROSIS

- Common and final pathway in several cardiomyopathies
- Consistent relationship between T1 mapping indices and myocardial fibrosis on histology
  - Non-contrast T1 values ↑
  - Post-contrast T1 values ↓
  - ECV values ↑

Non-contrast T1 values are increased and post-contrast values are decreased in multiple cardiomyopathies

Increased T1 values are associated with adverse outcomes

EDEMA

- Increased T1 and T2 values
- Typically co-localizes with LGE

Tako-Tsubo Cardiomyopathy

- Classic wall motion abnormality with apical ballooning
- Typically no LGE
- Increased non-contrast T1 and T2 values

Vermes E et al. JCMR 2015; 17(Suppl 1): P354
Cardiac Sarcoid

- Edema and inflammation identified with T2 imaging
- Fibrosis identified with LGE and T1 mapping
Amyloid

- Family of diseases induced by misfolded or misassembled proteins
- Non-contrast T1 and ECV values are elevated

Amyloid

- Diagnostic role in patients with severe renal impairment precluding safe administration of gadolinium contrast
- T1 values are higher in AL compared to ATTR

Anderson Fabry

- Rare X-linked disorder of lysosomal metabolism
- Non-contrast T1 values are decreased
- Pseudo-normalization in areas of fibrosis

Iron

- Iron is paramagnetic, causing inhomogeneity within the local magnetic field.
Iron

- Cardiac iron concentration is inversely related to myocardial T1 and T2* values
- T1 values correlate with T2*, and may be more reproducible

WHY

- Quantitative evaluation of diffuse myocardial changes including fibrosis and edema
- Diagnostic dilemma
- Prognostic significance
WHEN

- Track changes over time
- Detect subtle changes
- Inability to administer contrast
- Suspected Fabry disease
HOW

- T1, T2, and T2* sequences are available
- In line maps can be generated
- Off-line analysis possible with several vendors
- Values vary depending on several factors
Thank you!