Tutorial 3

Data acquisition protocol guide

The use of DCE-MRI in the evaluation of synovial and bone marrow activity in patients with arthritis has been tested on high-field scanners and low-field dedicated extremity scanners and seems capable of discriminating patients with clinically active disease from those in remission in both knee and wrist joints.

Although there is no general consensus regarding the best dynamic MRI protocol for DCE-MRI of joints with arthritis, this tutorial provides some general data acquisition guidelines and summarizes both published and unpublished MRI protocols for the last 8 years for wrists and knees using low field (0.2T) scanners and 1.5T or 3T scanners.

Glossary of Terms

DCE-MRI	Dynamic Contrast-Enhanced MRI
DICOM	Digital Imaging and Communications in Medicine standard file format
GRE	Gradient Echo
Healthy	Healthy normal persons
JIA	Juvenile arthritis
MCP	Metacarpophalangeal joints
Psa	Psoriasis arthritis
RA	Rheumatoid arthritis
SE	Spin Echo
Sec	Seconds
TE	Echo Time
TR	Repetition Time
UPA	Early undifferentiated arthritis

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1 General protocol guidelines

As explained in the User Manual, part of the functionality of Dynamika is to perform iMap calculations in which the signal intensity curve for each pixel in a time series is categorised as being one of three shapes: persistent, plateau or washout. It is therefore important that data acquisition is performed using parameters which will allow these shapes to be captured. The following subsections set out some general guidelines for data acquisition.

1.1 Scanner

Dynamika can be used with any kind of MRI scanner which is capable of producing time series data in the form of DICOM files. There is no requirement for any particular field strength of scanner. However, more powerful scanners tend to produce higher resolution data with a stronger contrast signal, which can often be more effectively analysed by Dynamika.

1.2 Noise

Whatever the variety of scanner, it is imperative that the acquisition protocol is designed so that acquisition noise is kept to a minimum. For example, entering or leaving the Faraday cage around the MRI scanner during a scan can result in artefacts in any data acquired, and so this should be avoided.

1.3 Patient Motion

Patient motion during a scan would normally inhibit analysis of DCE-MRI data because it is impossible to identify the same area of tissue in each frame, thereby prohibiting the comparison of signal intensities for that same tissue over time. This is not such a problem when using Dynamika because the software can correct for motion artefacts in dynamic scans.

However, motion should ideally be kept to a minimum. In particular, motion in a direction orthogonal to the image plane is very difficult to correct and should be avoided. For example, when acquiring axial images of a wrist, unintentional movement of the arm through the scanner should be avoided.

1.4 Time

Dynamika determines the contrast enhancement in each signal intensity curve by comparing the curve to a baseline signal, which is calculated from a number of baseline frames. The baseline frames must therefore be captured before contrast is injected into the subject. Ideally, Dynamika needs at least three baseline frames from which to calculate the baseline values.

After the contrast has been injected, if an insufficient number of frames are acquired during the contrast enhancement phase then the full shape of the intensity curve for each pixel will not be captured. It will then be impossible for Dynamika to identify that an intensity curve describes any of the desired shapes (i.e. persistent, plateau or washout). In a normal subject, 4-6 minutes is a sufficient amount of time to acquire the full contrast enhancement sequence, including both

a baseline period and a contrast enhancement period. It is not recommended that scans are performed which span less than 4 minutes.

It is also important that a sufficient number of acquisitions is performed during a scan. Ideally, as many acquisitions as possible should be performed during the scan. The amount of time between acquisitions should not exceed 15 seconds so as to ensure that the shape of the signal intensity curve is accurately represented. It is important to keep the parameters of each scan the same, including maintaining the same amount of time between acquisitions, because it is felt that this will enhance the comparability of results even when using different scanners.

1.5 Contrast

The rate at which contrast is injected into the patient is likely to have an effect on the shape of the signal intensity curve and, in particular, the rate of enhancement. It is therefore recommended that a power injector is used to administer the contrast. Using a power injector also allows for more precision in the timing of image acquisition relative to contrast injection.

1.6 Summary

- Any kind of MRI scanner capable of producing DICOM image files and suitable for DCE-MRI may be used with Dynamika
- Although Dynamika is capable of correcting noisy input data, patient movement and acquisition noise should ideally be kept to a minimum
- Scans should not be shorter than 4 minutes and should include:
    - three baseline frames;
    - enough contrast-enhanced frames to show the full signal intensity curve; and
    - ideally, each frame should not be more than 15 seconds apart
- If possible, a power injector should be used to inject the contrast.

2 Sample Protocols

This section provides a number of sample protocols for performing DCE-MRI. References are provided, where appropriate, to the published articles in relation to which these protocols have been used.

 **CAUTION**

Please note that not all of the protocols below conform to all of the advice given in Section 1. These protocols are provided for information and reference only.

2.1 Hands

Study Details	
Authors	Navalho M et al, Skeletal Radiol [1]
Year	2011
Anatomy	Both hands
Diagnosis	UPA
Number of patients	Unknown
Scanner	
Field strength	3T
MRI vendor	Siemens Magnetom Verio
Coil	Body
Contrast	
Contrast/weight	Magnevist Bayer 0.1mmol/kg
Injection rate	2.5ml/second
Scan Parameters	
Slice orientation	Coronal
DCE-sequence	3D GRE T1 (VIBE) with fat saturation
Flipangle degrees	10
TE (ms)	3.99
TR (ms)	9.29
Number of excitation	1
Fields of View	250mm
Matrix (Image dimensions)	256X256
Number of slices	46
Slicethickness	1.1mm
Time between acquisition	28 sec
Total image time	4min

Study Details	
Authors	Hodgson, R et al [5]
Year	2007
Anatomy	MCP

Diagnosis	RA
Number of patients	11
Scanner	
Field strength	3T
MRI vendor	Siemens Trio
Coil	Flex
Contrast	
Contrast/weight	Dotarem GUERBET 0.1 mmol/kg
Injection rate	approx 4ml/second
Scan Parameters	
Slice orientation	Axial
DCE-sequence	3D Spoiled GRE T1
Flipangle degrees	30
TE (ms)	2
TR (ms)	4.5
Number of excitation	1
Fields of View	100mm
Matrix (Image dimensions)	256x128
Number of slices	24
Slicethickness	1mm
Time between acquisition	13 sec
Total image time	5min

2.2 Wrist

Study Details	
Authors	Boesen, M et al [2]
Year	2011
Anatomy	Wrist
Diagnosis	RA/PSA/UPA
Number of patients	42 / 4 healthy
Scanner	
Field strength	0.2T
MRI vendor	Esaote
Coil	Wrist
Contrast	
Contrast/weight	Omniscan GE 0.2mmol/kg
Injection rate	approx 1ml/sec
Scan Parameters	
Slice orientation	Axial
DCE-sequence	SE T1
Flipangle degrees	90
TE (ms)	16
TR (ms)	100
Number of excitation	1
Fields of View	150mm
Matrix (Image dimensions)	160x128
Number of slices	3

Slicethickness	5mm
Time between acquisition	18 sec
Total image time	5min

Study Details	
Authors	Malattia, C et al [3]
Year	2010
Anatomy	Wrist
Diagnosis	JIA
Number of patients	unknown
Scanner	
Field strength	1.5T
MRI vendor	Philips Intera
Coil	Flex Small Coil
Contrast	
Contrast/weight	Magnevist Bayer 0.1mmol/kg
Injection rate	2ml/second
Scan Parameters	
Slice orientation	Coronal
DCE-sequence	3D GRE T1 FFE
Flipangle degrees	40
TE (ms)	1.7
TR (ms)	6
Number of excitation	1
Fields of View	Unknown
Matrix (Image dimensions)	109x320
Number of slices	40
Slicethickness	1.5
Time between acquisition	5 sec
Total image time	3min 20sec

Study Details	
Authors	Kubassova, O et al [4]
Year	2010
Anatomy	Wrist
Diagnosis	RA
Number of patients	140 / 5 healthy
Scanner	
Field strength	0.2T
MRI vendor	Esaote
Coil	Wrist
Contrast	
Contrast/weight	Magnevist Bayer 0.1mmol/kg
Injection rate	approx 1ml/second
Scan Parameters	

Slice orientation	Coronal
DCE-sequence	GRE T1
Flipangle degrees	75
TE (ms)	6
TR (ms)	60
Number of excitation	1
Fields of View	160mm
Matrix (Image dimensions)	256x128
Number of slices	3
Slicethickness	4mm
Time between acquisition	10 sec
Total image time	5min

Study Details	
Authors	Zierhut, M. L. et al [6]
Year	2007
Anatomy	Wrist
Diagnosis	RA
Number of patients	12
Scanner	
Field strength	1.5T
MRI vendor	GE Signa
Coil	Wrist
Contrast	
Contrast/weight	20ml Omniscan GE
Injection rate	approx 1ml/sec
Scan Parameters	
Slice orientation	Coronal
DCE-sequence	GRE T1
Flipangle degrees	70
TE (ms)	4.2
TR (ms)	35
Number of excitation	2
Fields of View	100mm
Matrix (Image dimensions)	128x256
Number of slices	1
Slicethickness	6-10mm
Time between acquisition	10sec
Total image time	5min

Study Details	
Authors	Palosaari, K. et al [7]
Year	2004
Anatomy	Wrist
Diagnosis	RA

Number of patients	28
Scanner	
Field strength	0.23T
MRI vendor	Philips
Coil	Wrist
Contrast	
Contrast/weight	15ml Magnevist Bayer
Injection rate	approx 1ml/sec
Scan Parameters	
Slice orientation	Coronal
DCE-sequence	GRE T1
Flipangle degrees	40
TE (ms)	10
TR (ms)	30
Number of excitation	1
Fields of View	160mm
Matrix (Image dimensions)	128x256
Number of slices	12
Slicethickness	2mm
Time between acquisition	69 sec
Total image time	5min 50sec

Study Details	
Authors	Cimmino, M. et al [8]
Year	2003
Anatomy	Wrist
Diagnosis	RA
Number of patients	36 / 5 healthy
Scanner	
Field strength	0.2T
MRI vendor	Esaote
Coil	Wrist
Contrast	
Contrast/weight	Magnevist Bayer 0.2mmol/kg
Injection rate	approx 1ml/sec
Scan Parameters	
Slice orientation	Axial
DCE-sequence	SE T1
Flipangle degrees	90
TE (ms)	16
TR (ms)	100
Number of excitation	1
Fields of View	160mm
Matrix (Image dimensions)	256x256
Number of slices	3
Slicethickness	5mm
Time between acquisition	12-18 sec

Total image time	5 min

Study Details	
Authors	Frederiksberg Hospital Denmark Dept of Radiology
Year	Unpublished
Anatomy	Wrist
Diagnosis	Unknown
Number of patients	unknown
Scanner	
Field strength	1.5T
MRI vendor	Philips Intera
Coil	Unknown
Contrast	
Contrast/weight	Prohance Bracco 0.1mmol/kg
Injection rate	2ml/sec
Scan Parameters	
Slice orientation	Coronal/axial
DCE-sequence	GRE T1 (Thrive)
Flipangle degrees	10
TE (ms)	1.73
TR (ms)	3.3
Number of excitation	Unknown
Fields of View	Unknown
Matrix (Image dimensions)	Unknown
Number of slices	10
Slicethickness	3mm
Time between acquisition	3 sec
Total image time	5 min

Study Details	
Authors	Frederiksberg Hospital Denmark Dept of Radiology
Year	Unpublished
Anatomy	Wrist
Diagnosis	Unknown
Number of patients	unknown
Scanner	
Field strength	3T
MRI vendor	Siemens Magnetom Verio
Coil	Unknown
Contrast	
Contrast/weight	Prohance Bracco 0.1mmol/kg
Injection rate	2ml/sec
Scan Parameters	
Slice orientation	Coronal/axial
DCE-sequence	GRE T1 (Vibe)

Flipangle degrees	15
TE (ms)	1.86
TR (ms)	5.5
Number of excitation	Unknown
Fields of View	Unknown
Matrix (Image dimensions)	Unknown
Number of slices	18
Slicethickness	3mm
Time between acquisition	9 sec
Total image time	5min

2.3 Knee

Study Details	
Authors	van der Leij, C et al [9]
Year	2009
Anatomy	knee
Diagnosis	RA
Number of patients	5 / 5 healthy
Scanner	
Field strength	1.5T
MRI vendor	General Electric Signa
Coil	Knee coil
Contrast	
Contrast/weight	Magnevist Bayer 0.1mg/kg
Injection rate	5ml/second
Scan Parameters	
Slice orientation	Axial
DCE-sequence	3D Gredient Echo
Flipangle degrees	30
TE (ms)	3.5
TR (ms)	8.1
Number of excitation	1
Fields of View	180mm
Matrix (Image dimensions)	256x256
Number of slices	20
Slicethickness	4mm
Time between acquisition	22 sec
Total image time	7min 19sec

2.4 Hip

Study Details	
Authors	Malattia, C et al [3]
Year	2010
Anatomy	Hip
Diagnosis	JIA

Number of patients	unknown
Scanner	
Field strength	1.5T
MRI vendor	Philips Intera
Coil	Body
Contrast	
Contrast/weight	Magnevist Bayer 0.1mmol/kg
Injection rate	2ml/second
Scan Parameters	
Slice orientation	Coronal
DCE-sequence	3D GRE T1 FFE
Flipangle degrees	40
TE (ms)	1.7
TR (ms)	6
Number of excitation	1
Fields of View	Unknown
Matrix (Image dimensions)	109x320
Number of slices	40
Slicethickness	1.5
Time between acquisition	5 sec
Total image time	3min 20sec

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