
Contents

1	Spin and the Nuclear Magnetic Resonance Phenomenon	1
2	Relaxation	7
2.1	T1: Longitudinal Relaxation	7
2.2	T2/T2*: Transverse Relaxation	8
3	Image Contrast	11
3.1	Repetition Time (TR) and T1 Weighting	12
3.2	Echo Time (TE) and T2 Weighting	13
3.3	Saturation at Short Repetition Times	15
3.4	Flip Angle (Tip Angle)	17
3.5	Presaturation	18
3.6	Magnetization Transfer	19
4	Slice Selection and Spatial Encoding	21
4.1	Three-Dimensional Spatial Encoding	26
4.2	K-Space	27
5	Factors Affecting the Signal-to-Noise Ratio	29
5.1	Pixel, Voxel, Matrix	30
5.2	Slice Thickness and Receiver Bandwidth	30
5.3	Field of View and Matrix	32
5.4	Number of Excitations	36
5.5	Imaging Parameters	36
5.6	Magnetic Field Strength	36
5.7	Coils	37
5.7.1	Volume Coils	37
5.7.2	Surface Coils	37
5.7.3	Intracavity Coils	37
5.7.4	Phased-Array Coils	38
6	The MR Scanner	41
6.1	The Magnet	42
6.2	The Gradient System	44
6.3	The Radiofrequency System	45
6.4	The Computer System	45

7	Basic Pulse Sequences	47
7.1.	Spin Echo (SE) Sequences	48
7.2	Black Blood Effect	49
7.3	Multislice Imaging	50
7.4	Inversion Recovery (IR) Sequences	50
7.5	STIR Sequences	52
7.6	FLAIR Sequences	52
7.7	Gradient Echo (GRE) Sequences	52
7.8	Multiecho Sequences	55
8	Fast Pulse Sequences	57
8.1	Fast or Turbo Spin Echo Sequences	57
8.2	Single-Shot Fast Spin Echo (SSFSE) Sequences	58
8.3	Fast or Turbo Inversion Recovery (Fast STIR) Sequences	59
8.4	Fast Gradient Echo (GRE) Sequences	59
8.5	Echo Planar Imaging (EPI) Sequence	60
8.6	Hybrid Sequences	60
8.7	Gradient and Spin Echo (GRASE) Sequence	61
8.8	Spiral Sequences	61
8.9	Echo Time and T2 Contrast in Fast Sequences	62
9	Fat Suppression Techniques	63
9.1	Chemical Shift Imaging	63
9.2	Frequency-Selective Fat Saturation	65
9.3	Short TI Inversion Recovery (STIR)	66
9.4	Spectral Presaturation with Inversion Recovery (SPIR)	66
10	Parallel Imaging	69
10.1	Background	69
10.2	Principles of Parallel Imaging	69
10.3	Special Requirements	71
10.4	Applications	71
11	Cardiovascular Imaging	73
11.1	Angiography	74
11.1.1	Bright Blood Imaging	74
11.1.2	Black Blood Imaging	86
11.1.3	Time-Resolved MR Angiography	88
11.2	Perfusion-Weighted Imaging	89
11.3	Diffusion-Weighted Imaging	91

11.4	The BOLD Effect in Functional Cerebral Imaging	95
11.5	Cardiac Imaging	97
11.6	Cardiac Imaging with SSFP Sequences	98
11.7	Myocardial Perfusion Imaging	99
11.8	Late-Enhancement Imaging	101
11.9	Detection of Increased Myocardial Iron Concentrations	102
12	MR Contrast Agents	103
12.1	Chemical Structure	107
12.2	Relaxivity	109
12.3	Pharmacologic Properties	112
12.3.1	Extracellular Contrast Agents	112
12.3.2	Intravascular or Blood Pool Contrast Agents	115
12.3.3	Liver-Specific Contrast Agents	116
12.3.4	RES Contrast Agents	118
12.3.5	Lymph Node-Specific Contrast Agents	119
12.3.6	Tumor-Targeted Contrast Agents	119
12.3.7	Other Emerging Tissue-Specific Contrast Agents	120
12.3.8	Hyperpolarized Gases	120
12.3.9	Oral MR Contrast Agents	121
12.4	Outlook	122
13	MR Artifacts	129
13.1	Motion and Flow Artifacts (Ghosting)	129
13.2	Phase Wrapping	131
13.3	Chemical Shift	133
13.4	Magnetic Susceptibility	135
13.5	Truncation Artifacts	135
13.6	Magic Angle	136
13.7	Eddy Currents	136
13.8	Partial Volume Artifacts	136
13.9	Inhomogeneous Fat Suppression	136
13.10	Zipper Artifacts	137
13.11	Crisscross or Herringbone Artifacts	137
14	High-Field Clinical MR Imaging	139
14.1	Tissue Contrast	140
14.2	Magnetic Susceptibility	140
14.3	Chemical Shift	140
14.4	Radiofrequency (RF) Absorption	141

15 Bioeffects and Safety	143
Glossary	147
Subject Index	165