

## **TABLE OF CONTENTS**

Preface to the Fifth Edition ix

Acknowledgments xi

List of Acronyms xiii

Equation symbols xvii

About the Companion Website xix

### **Chapter 1 Basic principles 1**

Introduction 1

Atomic structure 2

Motion in the atom 2

MR active nuclei 4

The hydrogen nucleus 5

Alignment 6

Net magnetic vector (NMV) 8

Precession and precessional (Larmor) frequency 10

Precessional phase 13

Resonance 13

MR signal 18

The free Induction decay(FDI) signal 20

Pulse timing parameters 22

### **Chapter 2 Image weighting and contrast 24**

Introduction 24

Image contrast 25

Relaxation 25

T1 recovery 26

T2 decay 27

Contrast mechanisms 31

Relaxation in different tissues 32

T1 contrast 36

T2 contrast 40

Proton density contrast 41

Weighting 42

Other contrast mechanisms 51

### **Chapter 3 Spin echo pulse sequences 58**

Introduction 58

RF rephasing 59

Conventional spin echo 65

Fast or turbo spin echo (FSE/TSE) 68

Inversion recovery (IR) 78

Short tau inversion recovery (STIR) 82

Fluid attenuated inversion recovery (FLAIR) 84

### **Chapter 4 Gradient echo pulse sequences 89**

Introduction 89

Variable flip angle 90

Gradient rephasing 91

Weighting in gradient echo pulse sequences 94

Coherent or rewound gradient echo 106

Incoherent or spoiled gradient echo 109

Reverse-echo gradient echo 113

Balanced gradient echo 119

Fast gradient echo 122

Echo planar imaging (EPI) 122

## **Chapter 5 Spatial encoding 128**

Introduction 128

Mechanism of gradients 129

Gradient axes 134

Slice-selection 135

Frequency encoding 142

Phase encoding 145

Bringing it all together – pulse sequence timing 152

## **Chapter 6 $k$ -space 158**

Introduction 158

Part 1 – what is  $k$ -space? 159

Part 2 - how are data acquired and how are images created from this data? 165

Part 3 –some important facts about  $k$ -space 184

Part 4: how do pulse sequences fill  $k$ -space? 197

Part 5: options that fill  $k$ -space 199

## **Chapter 7 Protocol optimization 209**

Introduction 209

Signal-to-noise ratio (SNR) 210

Contrast-to-noise ratio (CNR) 226

Spatial resolution 232

Scan time 237

Trade-offs 238

Protocol development and modification 238

## **Chapter 8 Artefacts 242**

Introduction 242

Phase mismapping 243

Aliasing 253

Chemical shift artefact 261

Out-of-phase signal cancellation 265

Magnetic susceptibility artefact 269

Truncation artefact 272

Cross-excitation/cross-talk 273

Zipper artefact 275

Shading artefact 276

Moiré artefact 277

Magic angle 279

Equipment faults 280

Flow artefacts 280

Flow-dependent (non-contrast enhanced) angiography 298

Black-blood imaging 303

Phase contrast MRA 304

## **Chapter 9 Instrumentation 311**

Introduction 311

Magnetism 313

Scanner configurations 315

Magnet system 318

Magnet shielding 326

Shim system 328

Gradient system 330

RF system 337

Patient transport system 343

Computer system and graphic user interface 344

## **Chapter 10 MRI safety 346**

Introduction (and disclaimer) 346

Definitions used in MRI safety 347

Psychological effects 350

The spatially-varying static field 351

Electromagnetic (radiofrequency) fields 357

Time-Varying Gradient Magnetic Fields 363

Cryogenics 365

Safety tips 367

Additional resources 368

Glossary 370

Index 387