Contents

Acknowledgments **7**

Abstract **9**

Resum **11**

Resumen **13**

0. Motivation **19**

1. Thesis Objectives and Structure **21**

2. Introduction **25**

2.1 Central Nervous System 25

2.1.1 Brain 25

2.1.2 Spinal Cord 26

2.1.3 Meninges 26

2.2 Cerebrospinal Fluid 28

2.2.1 Localization 28

2.2.2 CSF Physiology: Production, Absorption and Circulation 30

2.3 Vascular System 32

2.3.1 Arterial Blood Supply to the Brain and Spinal Cord 33

2.3.2 Capillaries 35

2.3.4 Venous Blood Drainage From the Brain and Spinal Cord 36

2.4 Intracranial Dynamic 37

2.5 Noninvasive Imaging Techniques for Flow study 39

2.6 Physical Principles of Nuclear MR 41

2.6.1 Origin of the MR Signal 42

2.6.2 Nuclear Spins in a Magnetic Field 43

2.6.3 Response of the Magnetization to a Radiofrequency Pulse 44

2.6.4 Basic Characteristics of the Magnetic Resonance Signal 47
2.6.5 Longitudinal and Transversal Relaxation 48
2.6.6 Spatial Encoding of the MR Signal 51
2.6.7 The *k*-space and the Matrix Image 55
2.7 Flow Quantification from Phase Contrast MR Imaging 55
2.7.1 Construction of the Image 56
2.7.2 Flow Sensitivity Adjustment 58
2.7.3 Cardiac Synchronization 60
2.7.4 Flow Quantification 62
2.7.5 Errors in the MR Volumetric Flow Measurements 63
3. Methods 69
3.1 Segmentation Techniques 70
3.1.1 Threshold Method 73
3.1.1.1 Aqueduct of Sylvius 75
3.1.1.2 Vascular Vessels 79
3.1.2 K-means Method 81
3.2 Aliasing Correction 88
3.3 Background Correction 91
3.4 PC-MRI Acquisition Protocols 93
3.5 Quantitative Analysis 96
3.5.1 Velocity Amplitude Parameters 97
3.5.2 Flow Amplitude Parameters 97
3.5.3 Flow Temporal Parameters 97
3.5.4 Intracranial Dynamic 98
3.6 Statistical Analysis 102
3.6.1 One-Way Analysis of Variance 102
3.6.2 Bland and Altman Plot 104

3.6.3 Intraclass Correlation Coefficient 104
3.6.4 Coefficient of Variation 104
3.6.5 Percent Error 105
4. Results 107
4.1 Threshold Method 107
4.1.1 Reproducibility and Comparison with other Methods 107
4.1.2 Estimation of the Background and Aliasing Correction 109
4.2 K-means Method 112
4.2.1 Reproducibility and Comparison with other Methods 112
4.2.2 Estimation of the Background and Aliasing Correction 116
4.2.3 Measurements 117
4.3 Factors that Influence on the PC Quantitative Analysis of CSF 120
4.3.1 Influence of the MR Field Strength and Circadian Rhythm 121
4.3.2 Influence of the Age and Gender 127
4.3.3 Normality Parameters 130
4.4 Clinical Applications 131
4.4.1 Aqueductal CSF Flow in White Matter Disease and NPH 131
4.4.2 Intracranial Dynamic 138
4.4.2.1 In Healthy Volunteers 138
4.4.2.1 In Neurological Disorders 143
5. Discussion 147
5.1 Threshold Method 147
5.2 K-mean Method 149
5.3 Factors that Influence on the PC Quantitative Analysis of CSF 153
5.3.1 Influence of the MR Field Strength and Circadian Cycle 153
5.3.2 Influence of the Subject's Age and Gender 154
5.4 Clinical Application 155

5.4.1 Aqueductal CSF Flow in White Matter Disease and NPH 155

5.4.2 Intracranial Dynamic 158

6. Conclusions 163

6.1 Reviews of Thesis Objectives 163

6.2 On the Future Work 165

Glossary 167

References 169

Thesis related publications 189

APPENDIX 1 195