## **Contents**

The Cardiac Conducting System and its Adminine Condu	
Anatomy of the Conducting System	1
Basic Cardiac Electrophysiology	3
The Initiation and Propagation of the Cardiac Impulse	4
Resetting the Sinoatrial Node Pacemaker	5 7
The Spread of the Impulse Through the Atria	7
The Functioning of the Atrioventricular Node	7
Does the Atrioventricular Node Conduct?	8
Autonomic Innervation of the Heart	9
Autonomic Control of the Sinoatrial Node	11
Autonomic Control of the Atrioventricular Node	13
2 The Pathophysiology of Atrial Fibrillation	19
Pathology	19
	20
The Electrophysiology of Atrial Fibrillation Electrophysiological Factors that Predispose to Atrial	
Fibrillation	22
Initiation of Atrial Fibrillation	23
The Mapping of Atrial Flutter and Fibrillation: The	
Essential Distinction Between Them	24
The Ventricular Response in Atrial Fibrillation	25
The Input to the Atrioventricular Node	25
The Ventricular Response in Atrial Fibrillation	26
The Role of the Autonomic Nervous System in Atrial	
Fibrillation	29
Autocorrelation and the Baroflex	30
Fibrillatory Waves in Atrial Fibrillation	36
The Brody Phenomenon in Atrial Fibrillation	36
The QT Interval in Atrial Fibrillation	37
Is the QT Interval in Atrial Fibrillation Different from that	
in Sinus Rhythm?	39
Atrial Fibrillation and the Wolff-Parkinson-White Syndrome	39
Aberration in Atrial Fibrillation	40
	70



viii Contents

3 Models of the Atrioventricular Node	4
The Electrophysiological Model of the Atrioventricular Node	4
Analogue Models of the Atrioventricular Node	4
Mathematical Models of the Atrioventricular Node in Atrial	•
Fibrillation	4
The Model of Cohen et al. (1983)	5
The Atrioventricular Node as a Biological Oscillator	5
The Model of Guevara and Glass (1982)	5
Resetting the Oscillator	5
The Response of a Sine-Wave Oscillator to a Rapid	)
Pandom Input	6
Random Input  The Effect of a Refractory Period on the Behaviour of the	U
Sine-Wave Model of the Atrioventricular Node	6
	O
What Values Should Be Assigned to the Sine-Wave Model's	-
Parameters?	6
More Electrophysiological Phenomena: Ventricular	_
Extrasystoles	6
The "Compensatory Pause" in Atrial Fibrillation	6
Peeling Back Refractoriness	6
The Effect of Right Ventricular Pacing in Atrial	_
Fibrillation	6
The Wolff-Parkinson-White Syndrome	7
Conclusions	7
Phase Resetting: An Achilles Heel	7
4 The Measurement of Cardiac Output in Sinus Rhythm and Atrial Fibrillation	7
Assessment of Cardiac Function	7
The Assessment of Cardiovascular Function	7
Measuring Volumetric Cardiac Output by the Fick Method.	7
The Indirect Fick Technique	7
Thermodilution	7
Reproducibility of Thermodilution	8
Measurement of Cardiac Output by Echocardiography and	_
Doppler Ultrasound	8
Measurement of Aortic Cross-Sectional Area	8
Measurement of Stroke Distance	8
Linear Cardiac Output	
Relationship Between Body Surface Area and Aortic Cross-	8
Relationship Between Body Surface Area and Aortic Cross-	
Relationship Between Body Surface Area and Aortic Cross- Sectional Area	8
Relationship Between Body Surface Area and Aortic Cross- Sectional Area	8
Relationship Between Body Surface Area and Aortic Cross- Sectional Area  Effect of Age and Blood Pressure on Aortic Size and Stroke Distance	8
Relationship Between Body Surface Area and Aortic Cross-Sectional Area  Effect of Age and Blood Pressure on Aortic Size and Stroke Distance  Expectations of Linear Cardiac Output	8
Relationship Between Body Surface Area and Aortic Cross-Sectional Area  Effect of Age and Blood Pressure on Aortic Size and Stroke Distance  Expectations of Linear Cardiac Output  Comparison between Thermodilution and Doppler	8
Relationship Between Body Surface Area and Aortic Cross-Sectional Area  Effect of Age and Blood Pressure on Aortic Size and Stroke Distance  Expectations of Linear Cardiac Output  Comparison between Thermodilution and Doppler Ultrasound	8888
Relationship Between Body Surface Area and Aortic Cross-Sectional Area  Effect of Age and Blood Pressure on Aortic Size and Stroke Distance  Expectations of Linear Cardiac Output  Comparison between Thermodilution and Doppler Ultrasound  Relationship Between Linear and Volumetric Cardiac Output	
Relationship Between Body Surface Area and Aortic Cross-Sectional Area  Effect of Age and Blood Pressure on Aortic Size and Stroke Distance  Expectations of Linear Cardiac Output  Comparison between Thermodilution and Doppler Ultrasound	8888

Contents ix

Average Stroke and Minute Distance in Atrial Fibrillation Beat-to-Beat Measurement of Stroke Output	92 93
5 The Haemodynamics of Atrial Fibrillation: The Development of a Model of Left Ventricular Function	95
The Relationship Between Time and Volume of the Pulse  Is Pulse Volume Irregularly Irregular?  Derivation of a Mathematical Model of Left Ventricular	95 96 99
Function  The Physiological Basis for the Mathematical Model of Left	
Ventricular Function  Effect of RR-1 on Stroke Distance: Preload  Effect of RR-1 on Stroke Distance: Contractility  The Effect of RR-1 on Stroke Distance: Afterload  Effect of RR-2 on Stroke Distance	100 100 102 104 104
Balance of Effects of RR-1 and RR-2	105
Pulsus Alternans Application of the Mathematical Model of Left Ventricular Function	106
Graphical Presentation of Multiple Regression Equation  Haemodynamic Consequences of Atrial Fibrillation	107 109
Venous Return Ventricular Filling	109 109
Mitral Regurgitation  Coronary Blood Flow	110
Regional Blood Flow	111 111
Endocrine Consequences of Atrial Fibrillation	111
6 The Haemodynamics of Atrial Fibrillation: The Effect of Ventricular Rate on Cardiac Output	115
Further Information from Multiple Regression Analysis  Three Haemodynamic Profiles  Relationship between Stroke and Minute Output  The Contribution of the Force-Frequency Effect to	115 116 118
Maintenance of Cardiac Output at High Ventricular Rates The Predicted Effect of Heart Rate on Cardiac Output in	120
Mitral Stenosis Effect of Irregularity Per Se on Cardiac Output	120 121
The Ventricular Rate for Maximum Cardiac Output The Predicted Ventricular Rate for Maximal Cardiac Output Relationship Between Slope of the Md/Mean VR Graph	122 122
and Ventricular Rate	123
Stroke Distance	123
Output	124

x Contents

The Ventricular Rate for Maximum Cardiac Output: Sinus Rhythm	
Comparison of Atrial Fibrillation and Sinus Rhythm	-
What is Meant by "Control" of Ventricular Rate?	:
A New Concept of Control of the Ventricular Rate in Atrial	
Fibrillation	1
7 The Use of the Haemodynamic Model of Atrial Fibrillation	
for Evaluating Drug Action	1
More Haemodynamic Profiles	1
Additional Haemodynamic Data Derived from Stroke	•
Distance	1
A Pilot Study of the Effect of Enoximone in Atrial Fibrillation	-
The Effect of Enoximone on the Haemodynamic Model	1
Control of Ventricular Rate While on Enoximone	-
	-
A Placebo Controlled Trial of Enoximone and Digoxin in	
Atrial Fibrillation	-
Conclusions	1
0.00	
8 The Autonomic Control of Ventricular Rate in Atrial	
Fibrillation	1
Respiratory Sinus Arrhythmia	1
Quantifying Respiratory Sinus Arrhythmia	1
Cheyne-Stokes Respiration	•
Respiratory Variation of P-R Intervals	
Modelling the Effect of the Vagus on the Atrioventricular	•
Modeling the Effect of the Vagus on the Athoventricular	
Node	
Respiratory Variation of Ventricular Rate in Atrial	
Fibrillation	•
Modelling the Action of the Vagus on the Ventricular	
Response to Atrial Fibrillation	-
Measurement of Baroreflex Function	-
Ramp Method	-
Neck-Suction Method	
Integration of Respiratory Sinus Arrhythmia and the	
Baroreflex	
The Frequency Response of the Heart Rate Control System	٠
A Systems Approach to Heart Rate Control	
The Effect of Ventricular Rate on Blood Pressure in Atrial	
Fibrillation	٠
The Effect of Ventricular Rate on Blood Pressure in Sinus	
Rhythm	
Regulation of Ventricular Rate in Atrial Fibrillation	
Conclusions	:
Concludions	•
0 Clinical Aspects of Atrial Fibrill-ti	
9 Clinical Aspects of Atrial Fibrillation	
Epidemiology	
Incidence	-

Contents xi

Prognosis	168
A stinio are	
Aetiology	169
Coronary Artery Disease	170
Myocardial Infarction	170
Valvular Heart Disease	171
Thyrotoxicosis	172
Alcohol	172
Metabolic Causes of Atrial Fibrillation	
	173
The Role of the Autonomic Nervous System in Precipitating	
Atrial Fibrillation	173
Physical Factors Precipitating Atrial Fibrillation	175
Iatrogenic Atrial Fibrillation	176
Self-Induced Atrial Fibrillation	177
Congenital and Familial Causes of Atrial Fibrillation	177
Infection and Infestation	178
	179
Malignancy	
Connective Tissue Disorders	179
The Acute Abdomen	179
Neurological Conditions	179
Respiratory and Sundry Conditions	180
Spontaneous Termination of Atrial Fibrillation	180
Thromboembolism	181
Prevalence of Thromboembolism in Atrial Fibrillation	181
Prevalence of Atrial Fibrillation in Thromboembolism	182
Prevalence of Stroke in Atrial Fibrillation	182
	183
The Prevalence of Atrial Fibrillation in Stroke	193
Intracardiac Infombi in Afrial Hibrillation	404
intracardiac infontor in Attract Formation	184
intracardiac finomorm / tima fromation	184
intracardiac finomorm zenar fromation	184
10 The Management of Atrial Fibrillation	199
10 The Management of Atrial Fibrillation	
10 The Management of Atrial Fibrillation	199
10 The Management of Atrial Fibrillation  Presentation	199 199 199
10 The Management of Atrial Fibrillation  Presentation  Symptoms  Signs	199 199 199 200
10 The Management of Atrial Fibrillation  Presentation  Symptoms  Signs  Investigations	199 199 199 200 200
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management	199 199 199 200 200 201
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate	199 199 200 200 201 201
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis	199 199 199 200 201 201 201 201
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers	199 199 200 200 201 201 201 205
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists	199 199 200 201 201 201 205 206
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists	199 199 200 201 201 201 205 206
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists Cardioversion	199 199 200 200 201 201 201 205
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists Cardioversion Selection of Patients for Cardioversion	199 199 200 200 201 201 205 206 208 209
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists  Cardioversion Selection of Patients for Cardioversion Complications of Cardioversion	199 199 200 201 201 201 205 206 208 209 209
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists Cardioversion Selection of Patients for Cardioversion Complications of Cardioversion Physiological Consequences of Cardioversion	199 199 200 201 201 201 205 208 209 210
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists  Cardioversion Selection of Patients for Cardioversion Complications of Cardioversion Physiological Consequences of Cardioversion Long-Term Results of Cardioversion	1999 1999 2000 2011 2011 2052 2082 2099 2100 2111
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists  Cardioversion Selection of Patients for Cardioversion Complications of Cardioversion Physiological Consequences of Cardioversion Long-Term Results of Cardioversion Chemical Cardioversion and Prevention of Atrial Fibrillation	199 199 200 201 201 205 208 209 210 211 211
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists  Cardioversion Selection of Patients for Cardioversion Complications of Cardioversion Physiological Consequences of Cardioversion Long-Term Results of Cardioversion Chemical Cardioversion and Prevention of Atrial Fibrillation Quinidine	199 199 200 201 201 205 208 209 210 211 211
10 The Management of Atrial Fibrillation  Presentation Symptoms Signs Investigations General Management Control of Ventricular Rate Digitalis Beta-adrenergic Blockers Calcium Antagonists  Cardioversion Selection of Patients for Cardioversion Complications of Cardioversion Physiological Consequences of Cardioversion Long-Term Results of Cardioversion Chemical Cardioversion and Prevention of Atrial Fibrillation	199 199 200 201 201 205 208 209 210 211 211

xii Contents

Propafenone	213
Digoxin	213
Beta-adrenergic Blockers	
Amiodarone	214
Flecainide and Other Class 1 Agents	215
Anticoagulant Therapy	215
Rheumatic Valve Disease	215
Non-rheumatic Atrial Fibrillation	216
Cardioversion	217
The Wolff-Parkinson-White Syndrome	217
	21/
New and Experimental Techniques in Atrial Fibrillation	010
Pacing	219
Internal Cardioversion	220
His Bundle Ablation	220
Surgical Treatment for Atrial Fibrillation	221
Appendix. A Simple Computer Model of the	
Electrophysiological System of the Heart, Considering	
the Sinoatrial and Atrioventricular Nodes as Sine Wave	
Oscillators	235
0.11 (7.1	000
Subject Index	239