

# Table of contents

<b>BASIC SCIENCE</b>	<b>1</b>	
<b>1. MECHANISMS OF ARRHYTHMIAS .....</b>	<b>1</b>	Autonomic nervous system and sudden death..... 18 Autonomic nervous system and neurally mediated syncope..... 20 References..... 21
Romain Pariaut, Lawrence Santistevan		
The concept of heterogeneity.....	1	
Abnormalities of impulse conduction.....	1	
Reentry.....	1	
Conduction disturbances .....	1	
Abnormalities of impulse formation.....	4	
Enhanced automaticity.....	6	Roberto Santilli, Dolores María Porteiro Vázquez
Enhanced abnormal automaticity .....	6	Classification of arrhythmias..... 23
Triggered activity.....	8	Hemodynamic consequences of arrhythmias ..... 24
Early afterdepolarizations .....	9	Clinical findings..... 28
Delayed afterdepolarizations .....	9	Physical examination..... 28
References.....	10	References..... 29
<b>2. INFLUENCE OF THE AUTONOMIC NERVOUS SYSTEM ON ARRHYTHMIAS .....</b>	<b>11</b>	
Manuela Perego, Alessandra Maffei		
Autonomic nervous system and sinus node .....	11	
Autonomic nervous system and atrioventricular node .....	12	Manuela Perego, Roberto Santilli
Autonomic nervous system and atrial fibrillation .....	12	Value and limitations of electrocardiography ..... 31
Autonomic nervous system and firing from the pulmonary veins and other sites.....	14	Electrocardiographic devices ..... 31
Autonomic nervous system and supraventricular tachycardias .....	15	The electrocardiograph ..... 31
Autonomic nervous system and ventricular arrhythmias.....	15	Holter monitoring..... 32
Autonomic nervous system and arrhythmias in heart diseases.....	15	Event recorders..... 32
Autonomic nervous system and heart failure .....	17	Electrophysiological study ..... 32
		Electrocardiogram lead systems ..... 33
		Systematic interpretation of the electrocardiogram..... 35
		Heart rate..... 35
		Rhythm ..... 35
		P wave..... 37
		PQ interval and segment..... 37

QRS complex .....	38	<b>6. ELECTROPHYSIOLOGICAL MAPPING .....</b>	79
ST segment .....	41	Roberto Santilli, Manuela Perego, Weihow Hsue	
T wave.....	41	Introduction .....	79
QT interval .....	42	Technique .....	79
Electrocardiographic clues to the electrophysiological mechanism of arrhythmias...	42	Basal electrophysiological study .....	80
Electrocardiographic features of narrow QRS complex tachycardias.....	44	Mapping supraventricular tachycardias .....	83
Diagnosis and evaluation of wide QRS complex tachycardias.....	48	Mapping ventricular tachycardias .....	89
Approach to bradyarrhythmias .....	49	3D electroanatomical mapping.....	92
References .....	52	References.....	98
<b>5. HOLTER MONITORING FOR ASSESSMENT AND MANAGEMENT OF ARRHYTHMIAS .....</b>	57	<b>THERAPEUTIC MODALITIES .....</b>	101
Roberto Santilli, Stefano Battaia			
Definition .....	57	<b>7. ANTIARRHYTHMIC THERAPY .....</b>	101
Indications for Holter monitoring.....	57	Manuela Perego, Lucia Ramera	
Technical aspects.....	57	General considerations.....	101
Recording.....	57	Drug classification.....	104
Artifacts .....	58	Use dependence .....	105
Reading procedure.....	59	Reverse use dependence .....	105
Heart rate variability analysis.....	62	Mechanisms of suppression of arrhythmia.....	105
Holter monitoring in dogs: normal findings.....	63	Proarrhythmic effects .....	105
Holter monitoring in cats: normal findings.....	64	Class 0 .....	106
Holter monitoring of different arrhythmias .....	65	Ivabradine .....	106
Supraventricular arrhythmias.....	65	Class Ia .....	106
Ventricular arrhythmias .....	68	Quinidine.....	106
Bradyarrhythmias .....	69	Procainamide.....	107
Conduction disorders .....	69	Disopyramide.....	108
Holter monitoring in the different disease states.	71	Class Ib .....	109
Dilated cardiomyopathy.....	71	Lidocaine.....	109
Arrhythmogenic cardiomyopathy.....	73	Mexiletine .....	111
Feline cardiomyopathies .....	73	Class Ic .....	112
Inherited ventricular arrhythmias.....	74	Propafenone .....	112
Myxomatous mitral valve disease .....	74	Flecainide.....	112
Subaortic stenosis.....	75	Class Id .....	113
Pacemaker function evaluation .....	75	Ranolazine .....	113
References .....	76	Class IIa .....	113
		Atenolol .....	113
		Carvedilol.....	114
		Esmolol.....	115

Metoprolol .....	115
Nadolol.....	116
Propranolol.....	117
Class IIb.....	118
Isoproterenol .....	118
Class IIc .....	118
Atropine .....	118
Glycopyrrolate.....	119
Class IIId.....	119
Digoxin .....	119
Class IIe .....	120
Aminophylline .....	120
Class IIIa.....	120
Amiodarone.....	120
Dronedarone.....	122
Class IIIb.....	122
Sotalol.....	122
Class IIIc .....	123
Vernakalant.....	123
Class IVa .....	123
Verapamil and diltiazem.....	123
References.....	126

<b>8. ANESTHESIA IN PATIENTS WITH ARRHYTHMIAS .....</b>	<b>129</b>
Stefania Scarabelli	
Introduction .....	129
Risk assessment .....	129
General considerations .....	130
Anesthetic drugs .....	130
Sedatives .....	130
Induction agents .....	130
Maintenance of general anesthesia .....	130
Anesthetic drugs and the conduction system .....	131
Anesthesia for electrophysiological procedures....	131
Anesthesia for electrophysiological studies and ablation procedures .....	134
Anesthesia for electrical cardioversion .....	134
Anesthesia for pacemaker implantation.....	135
References.....	135

## 9. ELECTRICAL CARDIOVERSION AND DEFIBRILLATION .....

137

Romain Pariaut	
Mechanisms of cardioversion and defibrillation .....	137
Equipment.....	138
Factors associated with defibrillation success .....	138
Shock configuration (monophasic vs. biphasic).....	138
Electrode position .....	139
Transthoracic impedance.....	139
Timing.....	139
Role of cardioversion and defibrillation in specific arrhythmias .....	139
Ventricular fibrillation and polymorphic and pulseless ventricular tachycardia.....	139
Monomorphic ventricular tachycardia.....	140
Atrial fibrillation .....	141
Supraventricular tachycardia .....	142
Complications .....	142
References.....	142

## 10. CARDIAC PACEMAKERS AND IMPLANTABLE CARDIOVERTER- DEFIBRILLATORS .....

143

Shana Mintz, Romain Pariaut	
Cardiac pacemakers .....	143
Indications for pacemaker therapy .....	143
Principles of pacing .....	143
Equipment .....	144
Implantation procedure .....	146
Device programming .....	149
Complications .....	151
Implantable cardioverter defibrillator .....	152
Equipment .....	154
Device programming.....	155
Role of implantable cardioverter-defibrillators in dogs with ventricular arrhythmias.....	155
References.....	156

<b>11. CATHETER ABLATION</b>	159
Roberto Santilli, Dolores María Porteiro Vázquez	
Indications for catheter ablation	159
Types of catheter ablation procedure	159
Radiofrequency catheter ablation	159
Cryoablation	160
Radiofrequency catheter ablation of supraventricular tachycardias	160
Accessory pathways	160
Focal atrial tachycardia	161
Atrial flutter	162
Radiofrequency catheter ablation of ventricular tachycardias	164
Radiofrequency catheter ablation of the atrioventricular node	167
References	167
<b>TACHYCARDIAS</b>	169
<b>12. SINUS TACHYCARDIA</b>	169
Manuela Perego	
Definition	169
Electrophysiological mechanism	169
Electrocardiographic findings	170
Clinical presentation	171
Therapy	171
References	173
<b>13. FOCAL ATRIAL ARRHYTHMIAS</b>	175
Roberto Santilli	
Definition	175
Electrophysiological mechanism	177
Electrocardiographic findings	178
Atrial ectopic beats	178
Atrial parastole	180
Atrial rhythms	180
Focal atrial tachycardias	182
Multifocal atrial tachycardia	183
Clinical presentation	185
Other methods of evaluation	185
Echocardiography	185
Electrophysiological study	186
Therapy	187
References	189
<b>14. JUNCTIONAL RHYTHMS AND JUNCTIONAL TACHYCARDIAS</b>	191
Manuela Perego	
Definition	191
Electrophysiological mechanism	192
Electrocardiographic findings	193
Junctional beats and rhythms	193
Junctional tachycardias	193
Clinical presentation	196
Other methods of evaluation	197
Echocardiography	197
Electrophysiological study	197
Therapy	199
References	200
<b>15. VENTRICULAR PREEXcitation AND ACCESSORY PATHWAY-MEDIATED TACHYCARDIAS</b>	203
Roberto Santilli	
Definition	203
Electrophysiological mechanism	204
Electrocardiographic findings	204
Ventricular preexcitation	205
Orthodromic atrioventricular reciprocating tachycardia	208
Permanent junctional reciprocating tachycardia	210
Preexcited tachycardias	211
Clinical presentation	212
Other methods of evaluation	214
Echocardiography	214
Electrophysiological study	214
Therapy	215
References	218

<b>16. ATRIAL FIBRILLATION</b>	219
Shana Mintz, Romain Paraut	
Definition	219
Electrophysiological mechanism	219
Electrocardiographic findings	220
Clinical presentation	221
Other methods of evaluation	224
Echocardiography	224
Electrophysiological study	224
Therapy	224
Rate control drugs	225
Rhythm control drugs	226
Rhythm control via electrical cardioversion	226
Rhythm control via radiofrequency catheter ablation	227
References	228
Polymorphic ventricular tachycardia	254
Ventricular fibrillation	254
Clinical presentation	254
Other methods of evaluation	255
Echocardiography	255
24-hour Holter monitoring/implantable loop recording	256
Electrophysiological study	256
Therapy	257
Decision to treat	257
Medical management	259
Acute treatment	259
Chronic treatment	260
Nonmedical management	260
References	261
<b>BRADYCARDIAS</b>	265
<b>17. MACROREENTRANT ATRIAL TACHYCARDIAS</b>	231
Roberto Santilli, Cortney Pelzek	
Definition	231
Electrophysiological mechanism	232
Anatomical reentry atrial flutters	233
Electrocardiographic findings	234
Cavotricuspid isthmus-dependent atrial flutter	235
Clinical presentation	237
Other methods of evaluation	238
Echocardiography	238
Electrophysiological study	238
Therapy	242
References	246
<b>18. VENTRICULAR ARRHYTHMIAS</b>	247
Romain Paraut	
Definition	247
Electrophysiological mechanism	248
Electrocardiographic findings	249
Ventricular ectopic beats	249
Ventricular parasystole	250
Accelerated idioventricular rhythm	251
Monomorphic ventricular tachycardia	253
<b>19. SINUS BRADYCARDIA</b>	265
Manuela Perego	
Definition	265
Electrophysiological mechanism	265
Electrocardiographic findings	267
Clinical presentation	269
Therapy	269
References	269
<b>20. SINUS NODE DYSFUNCTION</b>	271
Manuela Perego, Mara Bagardi	
Definition	271
Electrophysiological mechanism	271
Fundamentals of automaticity	275
Sinus node recovery time	277
Overdrive suppression	278
Atropine test	278
Sinus node remodeling and sinus node dysfunction	279
Electrocardiographic findings	280
Sinus bradycardia	280
Sinus arrest and sinoatrial exit block	281
Sinus standstill	281

Tachycardia-bradycardia and bradycardia-tachycardia syndromes .....	282	Electrophysiological study .....	327
Holter findings .....	282	Therapy.....	327
Echocardiography.....	286	Sinus exit blocks .....	327
Clinical presentation.....	286	Interatrial blocks .....	327
Therapy .....	287	Atrioventricular blocks.....	327
Pharmacological treatment .....	287	Intraventricular blocks.....	328
Cardiac pacing.....	287	References.....	329
Prognosis .....	287		
References.....	288		
<b>21. ATRIAL STANDSTILL</b>	291	<b>23. AGONAL RHYTHMS</b>	333
Romain Pariaut		Roberto Santilli	
Definition .....	291	Definition .....	333
Electrophysiological mechanism.....	292	Asystole .....	333
Electrocardiographic findings .....	292	Electrophysiological mechanism .....	333
Clinical presentation .....	292	Electrocardiographic findings .....	333
Evaluation methods.....	292	Therapy .....	333
Therapy.....	293	Ventricular fibrillation .....	335
References.....	295	Electrophysiological mechanism.....	335
		Electrocardiographic findings .....	336
		Therapy .....	336
		Pulseless electrical activity .....	336
		Electrophysiological mechanism.....	336
		Electrocardiographic findings .....	338
		Therapy .....	338
		References.....	339
<b>22. CONDUCTION DISTURBANCES</b>	297	<b>SPECIFIC DISEASES</b>	341
Roberto Santilli			
Definition .....	297	<b>24. FAMILIAL VENTRICULAR ARRHYTHMIAS</b>	341
Sinus node complex .....	298	Romain Pariaut	
Interatrial and internodal connections .....	299	Definition .....	341
Atrioventricular conduction axis .....	300	Ventricular arrhythmia in German Shepherd dogs .....	341
Electrophysiological mechanism.....	305	Ventricular arrhythmia in Rhodesian Ridgebacks .....	342
Sinus node exit block .....	305	Ventricular arrhythmia in Leonbergers.....	342
Interatrial block .....	305	Ventricular arrhythmia with long QT syndrome ....	343
Atrioventricular and intraventricular blocks.....	306	Treatment of familial ventricular arrhythmias .....	344
Electrocardiographic findings .....	310	References.....	345
Sinoatrial blocks.....	310		
Interatrial blocks .....	310		
Atrioventricular blocks.....	311		
Clinical presentation.....	323		
Atrioventricular blocks.....	323		
Other methods of evaluation .....	326		
Echocardiography .....	326		
Ambulatory electrocardiographic recording.....	326		

<b>25. ARRHYTHMIAS IN LEFT VENTRICULAR HYPERTROPHY</b>	347
Manuela Perego, Alessandra Maffei	
Definition .....	347
Pathophysiology .....	348
Clinical presentation .....	350
Arrhythmias in left ventricular hypertrophy .....	350
QRS complex abnormalities .....	350
Premature atrial ectopic beats and supraventricular tachycardias .....	351
Premature ventricular ectopic beats and ventricular tachycardias .....	351
Atrioventricular and intraventricular conduction blocks .....	352
Diagnosis .....	354
Prognosis .....	357
Treatment .....	357
References .....	359

<b>26. ARRHYTHMIAS IN DILATED CARDIOMYOPATHY</b>	361
Romain Pariaut	
Definition .....	361
Clinical presentation .....	361
Supraventricular arrhythmias in dilated cardiomyopathy .....	362
Atrial premature beats .....	362
Atrial fibrillation .....	362
Ventricular arrhythmias in dilated cardiomyopathy .....	364
Electrophysiological mechanism .....	364
Ventricular premature beats .....	364
Ventricular tachycardia .....	364
Identification of animals at high risk for sudden death .....	365
Therapy .....	367
Prevention of sudden cardiac death .....	367
Atrial fibrillation .....	368
Ventricular arrhythmias .....	368
References .....	368

<b>27. ARRHYTHMIAS IN MYOCARDITIS AND INFLAMMATORY CARDIOMYOPATHY</b>	371
Roberto Santilli	
Definition .....	371
Etiology of myocarditis .....	371
Pathophysiology of myocarditis .....	373
Clinical and instrumental findings .....	374
Echocardiography .....	374
Arrhythmias in myocarditis .....	375
Biomarkers and viral serology .....	378
Endomyocardial biopsy .....	378
Therapy .....	379
References .....	380

<b>28. ARRHYTHMIAS IN ARRHYTHMOGENIC CARDIOMYOPATHY</b>	383
Romain Pariaut	
Definition .....	383
Pathophysiology .....	383
Clinical presentation .....	384
Supraventricular arrhythmias in arrhythmogenic cardiomyopathy .....	385
Ventricular arrhythmias in arrhythmogenic cardiomyopathy .....	385
Electrophysiological mechanism .....	385
Ventricular premature complexes .....	385
Ventricular tachycardia .....	386
Identification of animals at high risk for sudden death .....	387
Diagnosis .....	388
Therapy .....	390
Medical therapy .....	390
Radiofrequency catheter ablation .....	392
Implantable devices .....	392
References .....	393

<b>29. ARRHYTHMIA-INDUCED CARDIOMYOPATHY</b>	395	<b>32. SYNCOPE</b>	421
Manuela Perego		Roberto Santilli, Manuela Perego	
Definition	395	Pathophysiology and classification	421
Pathophysiology	395	Cardiac syncope	423
Clinical presentation	396	Reflex syncope	424
Diagnosis	396	Vasovagal syncope	424
Therapy	399	Situational syncope	425
Arrhythmia-specific diagnostic tests and treatment	399	Carotid sinus syncope	426
Prognosis	403	Orthostatic hypotension syncope	426
References	404	Diagnosis of syncope	427
		History and clinical presentation	427
		Diagnostic tests	428
		Prognosis of syncope	432
		Therapy	432
		References	433
<b>30. ARRHYTHMIAS IN MITRAL VALVE DISEASE</b>	405	<b>33. SUDDEN CARDIAC DEATH</b>	435
Romain Paraut		Roberto Santilli, Stefano Battaia	
Definition	405	Definition	435
Electrophysiological mechanism	406	Causes of sudden cardiac death and associated diseases	435
Clinical presentation	407	Mechanism of sudden cardiac death	435
Therapy	407	Relationship between structure and function	435
References	408	Tachyarrhythmia vs. bradyarrhythmia during sudden cardiac death	437
		Arrhythmogenic mechanism of the different causes of sudden cardiac death, epidemiology, and risk stratification	439
<b>31. ARRHYTHMIAS IN SYSTEMIC DISORDERS</b>	411	Dilated cardiomyopathy	439
Manuela Perego, Lucia Ramera		Arrhythmogenic cardiomyopathy	440
Electrolyte disturbances	411	Hypertrophic cardiomyopathy	441
Hypokalemia	411	Coronary artery abnormalities	441
Hyperkalemia	411	Subaortic stenosis	441
Hypomagnesemia	413	Myocarditis	442
Chagas' disease	413	Acute heart failure	442
Viper envenomation	415	Bradyarrhythmias	442
Obstructive sleep apnea	415	Tachycardia-induced cardiomyopathy	442
References	418	Primary electrical disease	443
		Prevention of sudden cardiac death	443
		References	444