VETERINARY INTERNAL MEDICINE

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EDWARD FELDMAN
FEDERICO FRACASSI

CANINE NEUROLOGY

EDITORS

Luisa De Risio
Gualtiero Gandini

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Dr. Feldman has coedited the last six editions of The Textbook of Veterinary Internal Medicine with Dr. Stephen Ettinger and the last two also with Dr. Etienne Côté. He coauthored the four editions of Canine and Feline Endocrinology with Dr. Richard Nelson and the 4th edition also with Drs. Claudia Reusch, Catharine Scott-Moncrieff, and Ellen Behrend. He coedited Feline Endocrinology with Dr. Fracassi and Dr. Peterson.
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Dr. Luisa De Risio is a boarded veterinary neurologist with experience in conducting and leading research in academia, nonprofit organisations and industry. She earned her degree in Veterinary Medicine and her PhD from the University of Parma (Italy) in 1996 and 2020, respectively. She also completed an internship at a small animal referral hospital in Paris (France) and trained as a neurologist and neurosurgeon at North Carolina State University (USA). She became a Diplomate of the European College of Veterinary Neurology in 2004. Luisa was Faculty at the University of Parma until 2005 when she moved to the UK to become the Head of Neurology and subsequently Head of Research at the Animal Health Trust. Luisa joined Mars as a Clinical Research Director for Linnaeus in January 2000 and built a comprehensive program of clinical research support for Linnaeus Associates, fostering mutuality and productive scientific collaborations with other divisions in Mars Petcare. Luisa has been appointed as MVH global Director, Associate Research and joined the MVH Medical Affairs Science Team on 1 January 2025.

Luisa has worked with and led teams of people with different backgrounds, nationalities, and cultures. She achieved the Level 5 Certificate in Leadership and Management from the Institute of Leadership and Management in 2017, the Fellowship by Meritorious Contributions to Clinical Practice by the Royal College of Veterinary Surgeons in 2018, the Postgraduate Certificate in Veterinary Education at the Royal Veterinary College in 2020, and the Postgraduate Certificate in International Animal Welfare, Ethics and Law at the University of Edinburgh in 2025. She has been Honorary Professor of Veterinary Neurology at Nottingham Trent University (2021–2024) and vice president of the European College of Veterinary Neurology (2022–2024). Luisa has lectured at numerous continuing education and scientific meetings, published more than 100 papers in peer-reviewed journals, written numerous book chapters, and edited two textbooks on canine and feline seizure disorders.

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He is an expert of the European System of Evaluation of Veterinary Training (ESEVT) within the European Association of Establishments for Veterinary Education (EAEVE). From 2015 to 2021, he directed the degree programme in veterinary medicine of the University of Bologna. From 2017 to 2021, he was the National Representative of the European Board of Veterinary Specialization (EBVS) for Italy. Dr. Gandini has lectured in more than 150 national and international courses and has been an invited speaker at over 35 national and international congresses. He has also organized the four European editions of the international neurology *"Brain Camp" - Veterinary Neuroscience Course* for residents in neurology. He is an author/coauthor of more than 100 scientific publications, 71 in peer-reviewed international journals.

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Series preface

"Oh! You are a veterinarian? I (or my brother, my sister, my son, my daughter…) always wanted to be a veterinarian." All of us, as veterinary students and later as veterinarians, have often heard comments like this. Becoming a veterinarian seems to be such a wonderful career to nonveterinarians: helping helpless dogs and cats. Veterinarians should be happy and satisfied in their *chosen* profession because they are able to earn a living by caring for loved pets. The journey to satisfaction and happiness for veterinarians, however, never seems to follow an obvious, straight, or level path.

The 1950s witnessed a dramatic growth in the popularity of pet dogs and in the number of veterinarians who cared exclusively for pets. The popularity of cats soon followed. Today, more dogs and cats are considered "members of the family" than ever before in human history, and their owners want to protect their family members from illness or to resolve any illness. There are more veterinarians who care for dogs and cats currently than ever before in human history. Veterinary medicine has evolved remarkably to meet the ever-growing medical care expectations and demands of dog and cat owners.

When learning of a diagnosis, prognosis, treatment, and/or the cost of care for their ill pet, some owners become distressed. These emotions are often directed at the "messenger" of the bad news: the veterinarian. The veterinarian, in turn, may not respect their own knowledge and feel inadequate. One reason that a veterinarian may feel inadequate is the realization that it is impossible for anyone in general practice to be expert and current on all the canine and feline conditions encountered in a day, week, or month: everything from orthopedics to oncology, from vaccinology to dermatology, from ophthalmology to cardiology. Nor is it possible for an internal medicine specialist to be expert and current in each condition they encounter, from endocrinology to gastroenterology or from respiratory conditions to chronic kidney disease. Further, it is clear that cats are not small dogs. Perceived "knowledge deficiencies" can cause veterinarians to feel they are failing to meet their clients' expectations.

The internal medicine textbooks in this new series offer one approach for enjoying veterinary practice. We encourage colleagues to embrace developing expertise in one area. By focusing on and studying one organ system in either the dog or cat, one can achieve greater knowledge and skills and, in turn, greater confidence. Each book in this series offers a clear path to learning current opinions on pathophysiology, diagnosis, treatment, prognosis, and costs associated with illnesses involving one system in one species. Confidence gained in a focused area can be sensed by devoted owners. Further, confidence in one area of internal medicine also creates confidence in sharing limitations: "I am extremely confident in diagnosing and managing some conditions but I lack that level of expertise in all other conditions".

The books in this series have been constructed to help build expertise in one organ system in either the dog or the cat. Each book is edited by one or two specialists with outstanding international credentials. Each editor was tasked with building a text that contains all the information found in general internal medicine textbooks, but with much more in-depth discussions on each condition. Each book has early chapters focusing on differential diagnoses of owner concerns, physical examination findings, and laboratory and/or imaging results. These are excellent for students as they begin to apply their basic knowledge to clinical cases. These chapters also provide a quick review for experienced general practitioners and specialists. Each chapter provides at least one algorithm designed to take the reader from a vague owner concern, physical examination finding, or laboratory abnormality to a specific diagnosis with step-by-step instructions. The "techniques section" in each text teaches currently employed procedures, most with videos. In-depth chapters on known illnesses comprise 70 to 80% of each book's content. The editors have provided a larger number of chapters, a larger number of expert contributors, and greater depth on each organ system than any general textbook can supply. The material has a level of credibility that no internet site can claim. Each book can guide the reader through a more complete journey of understanding than is available in any other veterinary resource.

Edward Feldman
Federico Fracassi

Preface

It has been an honour and a privilege to contribute the Canine neurology textbook to the novel Veterinary Internal Medicine Series led by Prof. Ed Feldman and Prof. Federico Fracassi.

Neurology is a rapidly evolving and advancing field, often perceived as challenging and intimidating. This new textbook, entirely dedicated to canine neurology, provides up-to-date, evidence-based, clinically applicable information to support veterinary practitioners both in primary and secondary care. The aim is to improve knowledge and confidence in dealing with the neurology canine patient and promote contextualized care to benefit the patients, their owners, and the veterinary team. This book is also a precious resource for house officers and residents studying for board examination and for veterinary interns and students wishing to deepen their knowledge of neurology.

The book comprises four sections and includes figures, videos, tables, and algorithms to provide both quick access to key practical information and more in-depth knowledge. The first section includes short chapters focused on common neurologic presentations based on the owner's presenting concerns and/or physical examination findings. Each chapter includes an algorithm to provide visually engaging and easily accessible information on clinical approach, differential diagnoses, diagnostic investigations, and treatment. The second section focuses on the foundations of clinical neurology: an accurate approach to the neurology patient, a well-conducted neurologic examination, and correct interpretation of the findings to establish a robust neuroanatomic localization and a differential diagnosis list. The third section provides insights into diagnostic procedures, including laboratory investigations, neuroimaging, and electrodiagnostics. The fourth section of the book provides comprehensive yet accessible evidence-based and clinically relevant information on numerous neurologic disorders. Each chapter includes details on pathophysiology, diagnosis, treatment, and prognosis; helpful illustrations and videos; and a key points box to highlight essential information.

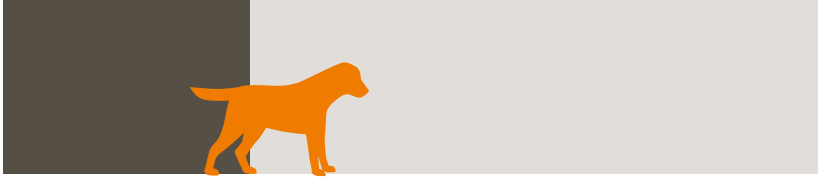
This textbook is the result of the dedication and expertise of a global team of authors with the excellent support of EDRA's Costanza Smeraldi and Melissa Testa, overseen by Prof. Ed Feldman and Prof. Federico Fracassi. It has been wonderful to work with you all, an absolute dream team!

We hope that this textbook will equip the readers with the knowledge, skills, and confidence to optimize the care they provide to their neurology patients and bring joy in their clinical practice. Equally, we hope it will spark their interest in further advancing clinical neurology and engaging in lifelong learning.

Luisa De Risio
Gualtiero Gandini

The Editors endorse the WSAVA position statement on cosmetic alterations in companion animals.
Please see the whole WSAVA statement at the following webpage:

https://wsava.org/wp-content/uploads/2024/02/WSAVA-Position-Statement-on-Cosmetic-Alterations-in-Companion-Animals.pdf



Abbreviations

Ab antibody
ABC airway, breathing, circulation
ABR auditory brainstem response
ACP acute canine polyradiculoneuritis
ACVIM American College of Veterinary Internal Medicine
AD Alzheimer's disease
ADC apparent diffusion coefficient
AE adverse effect
AF annulus fibrosus
AILP acquired idiopathic laryngeal paralysis
ALP alkaline phosphatase
ALS amyotrophic lateral sclerosis
ALT alanine aminotransferase
Angio SNAP serum antigen test for Angiostrongylus vasorum
ANNPE acute noncompressive nucleus pulposus extrusion
APPs acute-phase proteins
aPTT activated partial thromboplastin time
ARAS ascending reticular activating system
ASD antiseizure drug
ASM antiseizure medication
AST aspartate aminotransferase
Aβ amyloid beta
BAEPs brainstem auditory evoked potentials
BAER brainstem auditory evoked response
BAST bile acid stimulation test
BBB blood–brain barrier
BD bladder dysfunction
BDNF brain-derived neurotrophic factor
BID twice a day
BUN blood urea nitrogen
BVA British Veterinary Association
BWST body weight supported treadmill
CBC complete blood count
CBD cannabidiol
CBF cerebral blood flow
CCDS canine cognitive dysfunction syndrome
CCG cranial cervical ganglion
CCSM caudal cervical spondylomyelopathy
CDPs cord dorsum potentials
CE clinical examination
CISS constructive interference in steady state
CK creatine kinase
CKCS Cavalier King Charles Spaniel
CM Chiari malformation
CMAP compound muscle action potential
CMG caudal mesenteric ganglia
CM-N Chiari malformation – normal
CM-P Chiari malformation – pain
CN cranial nerve
CNS central nervous system
CO client-owned
CPSP central poststroke pain
CPTs choroid plexus tumors
CRDs complex repetitive discharges
CRI constant rate infusion
CRP C-reactive protein
CS cluster seizures
CSF cerebrospinal fluid
CSM cervical spondylomyelopathy
CT computed tomography
CVA cerebrovascular accident
DA-CSM disc-associated cervical spondylomyelopathy
DEEH disc-associated extensive epidural hemorrhage
DISH diffuse idiopathic spinal hyperostosis
DISHAAL disorientation, changes in social interactions, disturbances in the sleep/wake cycle, house soiling, activity changes, anxiety, loss of learning
DLSS degenerative lumbosacral stenosis
DM degenerative myelopathy
DPMS descending pain modulatory system
DWI diffusion-weighted imaging
DZP diazepam
ECG electrocardiogram
ED extradurally
EDX electrodiagnostic
EEG electroencephalography
EFS episodic falling syndrome
EMG electromyography
EPS endplate spikes
ERG electroretinography
ESP erector spinae plane
EUS external urethral sphincter
FC fecal continence
FCEM fibrocartilaginous embolic myelopathy
FINFUN Finnish neurological functional testing battery
FLAIR fluid-attenuated inversion recovery
fT4 free thyroxin
FVNUO facial and vestibular neuropathy of unknown origin
GABA gamma-aminobutyric acid
GE gradient echo
GFAP glial fibrillary acidic protein
GGT gamma-glutamyl transferase
GME granulomatous meningoencephalomyelitis
GP general proprioceptive
HNPE hydrated nucleus pulposus extrusion
HPA hypothalamic–pituitary–adrenal
HRQoL health-related quality of life
IASP International Association for the Study of Pain
iCa ionized calcium
ICH intracranial hypertension
ICP intracranial pressure
ID intradural
IE idiopathic epilepsy
IFN Idiopathic facial neuropathy
IHTS idiopathic head tremor syndrome
IIVDE intradural intraparenchymal disc extrusion
IM intramedullary
IM intramuscular, intramuscularly

IMP imepitoin
IN intranasal
IPVD idiopathic peripheral vestibular disease
ITN Idiopathic trigeminal neuropathy/trigeminal neuritis
IUS internal urethral sphincter
IV intravenous, intravenously
IVD intervertebral disc
IVDD intervertebral disc disease
IVDE Hansen type I intervertebral disc extrusion
IVDH intervertebral disc herniation
IVDP Hansen type II intervertebral disc protrusion
IVETF International Veterinary Epilepsy Task Force
IVS idiopathic vestibular syndrome
KBr potassium bromide
LASER light amplification by stimulated emission of radiation
LEV levetiracetam
LFB Luxol fast blue
LMN lower motor neuron
LUT lower urinary tract
LUTI lower urinary tract infection
MAO-B monoamine oxidase
MCT medium-chain triglyceride
MDZ midazolam
MEPPs miniature endplate potentials
MEPs motor evoked potentials
MFS modified Frankel score
MG myasthenia gravis
MGBA microbiota–gut–brain axis
MLF medial longitudinal fasciculus
MNCS motor nerve conduction studies
MRI magnetic resonance imaging
MST median survival times
MUAP motor unit action potential
MUO meningoencephalomyelitis of unknown origin
NAD nicotinamide adenine dinucleotide
NBD neurogenic bladder dysfunction
NDP negative deep pain
NE necrotizing encephalitis
NeuPSIG Neuropathic Pain Special Interest group
NION Noninfectious, idiopathic optic neuritis
NLE necrotizing leukoencephalitis
NM neuromuscular
NMDA N-methyl-D-aspartate
NMDA–R N-methyl-D-aspartate receptor
NME necrotizing meningoencephalitis
NMES neuromuscular electrical stimulation
NMJ neuromuscular junction
NP nucleus pulposus
NSAID nonsteroidal anti-inflammatory drug
NST Nerve sheath tumor
OA-CSM osseous-associated cervical spondylomyelopathy
OMI otitis media/interna
PARR polymerase chain reaction for antigen receptor rearrangements
PAS periodic acid–Schiff
PB phenobarbital
PBMT photobiomodulation therapy
PCR polymerase chain reaction
PG pelvic ganglia
PGE prostaglandin E
PGSD paroxismal gluten-sensitive dyskinesia
PKD paroxysmal kinesigenic dyskinesia
PLR pupillary light reflex
PLs pelvic limbs
PLT platelet
PMC pontine micturition center
PMM progressive myelomalacia
PMMA polymethyl methacrylate
PN polyneuropathy
PNH peripheral nerve hyperexcitability
PNKD paroxysmal nonkinesigenic dyskinesia
PNS peripheral nervous system
PNST peripheral nerve sheath tumor
PO per os, orally
PRN pro re nata (when required)
PROM passive range of motion
PSRF pedicle-screw rod fixation
PT prothrombin time
PTs primary tumors
PU/PD polyuria/polydipsia
PVD peripheral vestibular disease
QID 4 times a day
QoL quality of life
QST Quantitative Sensory Testing
R rectal
RBC red blood cells
RCT randomized controlled trial
RGC retinal ganglion cell
RNS repetitive nerve stimulation
RT radiation therapy/treatment
SAA serum amyloid A
SAD spinal arachnoid diverticula
SAMe S-adenosyl-L-methionine
SAMS spinocerebellar ataxia with myokymia and/or seizures
SB serum biochemistry
SBA serum bile acid
SC subcutaneously
SC subcutaneous injection
SC spinal cord
SCM serum concentration monitoring
SCWT Soft Coated Wheaten Terrier
SE status epilepticus
SM syringomyelia
SM-M syringomyelia – mild
SM-S syringomyelia – severe
SNAPs sensory nerve action potentials
SNCS sensory nerve conduction studies
SNPs single nucleotide polymorphisms
SPA spontaneous pathological activity
SPE serum protein eletrophoresis
SPFs seizure-precipitating factors
SRMA steroid-responsive meningitis-arteritis
SSEPs somatosensory evoked potentials
STIR short tau inversion recovery
STs secondary tumors
SW susceptibility weighted
T1W T1-weighted
T2W T2-weighted
tCa total calcium
TCA tricyclic antidepressants
TENS transcutaneous electrical nerve stimulation
TIA transient ischemic attack
TID 3 times a day
TLs thoracic limbs
TNCC total nucleated cell count
TOF time-of-flight
TPM topiramate
TSH thyroid-stimulating hormone
TT4 total thyroxin
UA urinalysis
UAR utricle asymmetricity ratio
UC urinary continence
UMN upper motor neuron
VD vestibular disease
VEPs visual evoked potentials
VGKC voltage-gated potassium channel
WBC white blood cell
WC window center
WGS whole genome sequence
WSAVA World Small Animal Veterinary Association
WW window width
ZNS zonisamide