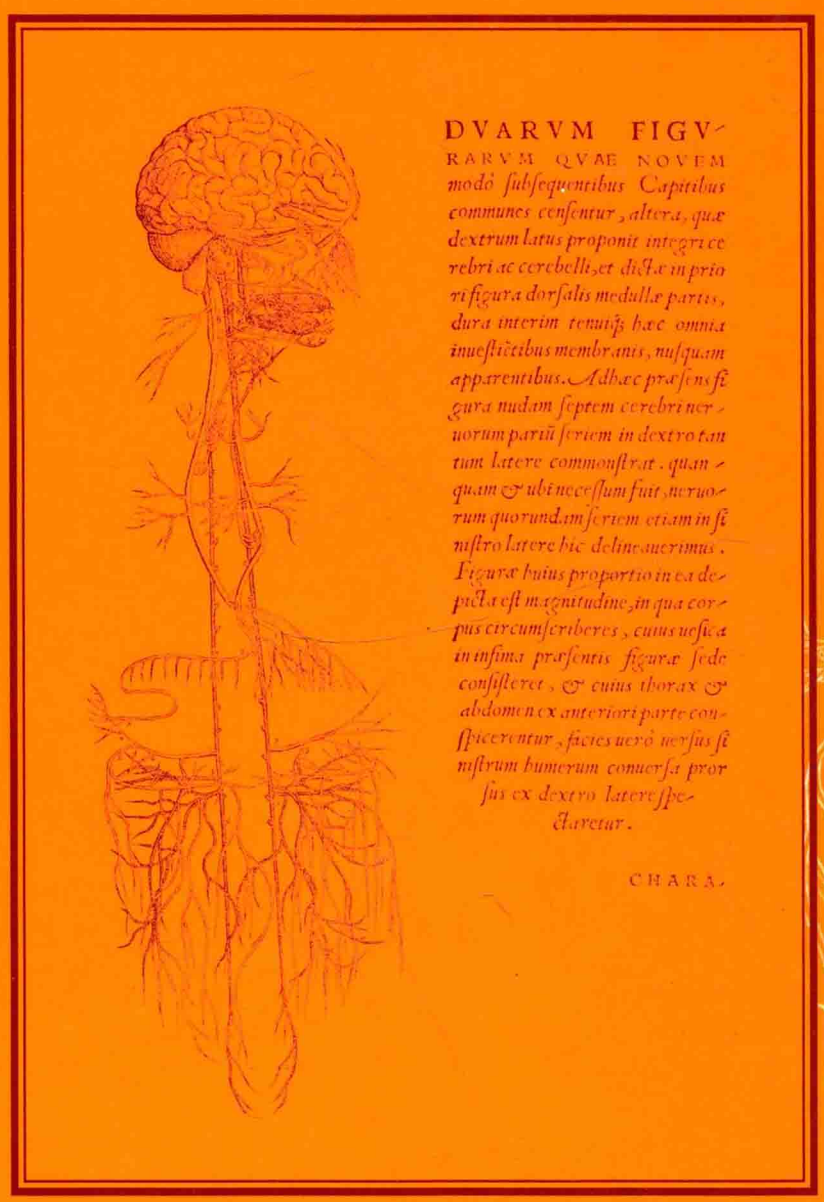
Clinical Neurophysiology, Volume 2

EEG, Paediatric Neurophysiology, Special Techniques and Applications

Edited by: Colin Binnie, Ray Cooper, François Mauguière, John Osselton, Pamela Prior and Brian Tedman



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Clinical Neurophysiology, Volume 2

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The cover of this book shows a drawing of a dissection of the nervous system by Andreas Vesalius (1514–1564) which is in the Library of the Royal College of Physicians in London.

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Preface

The cover of this book shows a drawing of a dissection of the nervous system by Andreas Vesalius (1514–1564) which is in the Library of the Royal College of Physicians in London. It was probably drawn by Jan Stephan van Calcar, a Flemish artist working in Venice and a pupil of Titian (Carlino, 1999), and is taken from Vesalius' *De humani corporis fabrica* (Liber III, page 319) which was published in Basel by Joannes Oporinus in 1543. This seminal anatomical text predated by a few decades the appearance of the *'Non Solus'* emblem (bottom right of the cover) on books published by the original Elsevier family in the Low Countries (Hartz, 1955). Unlike the traditional anatomy teachers, Vesalius performed the dissections himself; born in Brussels, he was one of the important circle of scientists working at the University of Padua in the sixteenth century whose careful observations, discourse and lectures led to the understanding of the overlap between structure and function that has formed the basis of clinical teaching since that time (Rossetti, 1985; Davenport, 2002). We believe that the Clinical Neurophysiology team of today should follow a similar tradition of an interactive multidisciplinary group – with a strong foundation in neuroanatomy and neurophysiology, high standards of practical technological skills as well as those deriving from considerable experience in the clinical neurosciences.

It is an exciting time in clinical neurophysiology. The impact of digital technologies and the possibilities of quantification, statistical treatment and advanced signal processing techniques, including expert systems, have enabled us to work to much more rigorous scientific standards. The increasing availability of such tools in our daily clinical work, together with the broad understanding of computers amongst all our staff, mean that patients can now benefit from investigations of known specificity and sensitivity. Further, as will be seen from Erik Stålberg's account of the integrated digital clinical neurophysiology laboratory in the final section of the present volume, there have been unexpected benefits in terms of help in training and the development and support of services in countries where these have not previously been available.

These technological changes have been developing during the gestation of this book and mean that the subsequent electronic versions which are planned by Elsevier will allow regular revision – and direct access to digital waveforms will allow aficionados to study morphologies *ad libitum*! Publication of a completely revised and expanded Companion Volume covering EMG, nerve conduction and evoked potentials (updating Osselton *et al.*, 1995) in a similar manner will follow later this year. We are grateful to the present house of Elsevier, the acknowledged experts in this relatively new field, for these possibilities.

Our two volumes were conceived in a somewhat unusual way, growing out of the popular practical approach used in previous books by some of the editorial team and planned as an integrated whole to provide a new comprehensive textbook. We have tried to treat the three main branches of clinical neurophysiology – peripheral neurophysiology, evoked potentials and electroencephalography – in a consistent and integrated way. Our aim is that the reader should understand exactly how to choose and to undertake appropriate investigations, and how to interpret the findings in the light of the latest evidence-based studies. Using historical evidence and illustrative case reports, we address the scientific principles, both biological and electrical, recording techniques, the development and characteristics of electrical potentials in normal subjects, and the ways in which these are disturbed by physical factors or disease. This foundation should enable the reader to interpret recordings from first principles. The main clinical sections are set in the context of typical referral problems or disease groups, showing how the appropriate sequence of investigations and their interpretation help in diagnosis or surveillance of the patient's condition.

The main authors/editors wrote a detailed master plan together, specifying in considerable detail the brief for the 31 specially invited contributors who worked closely with the editors. This collegiate approach has resulted in a closely interwoven text which has received the detailed attention of many people with a wide range of expertise – as to who wrote which sentence, we can only take collective responsibility! We believe that the end-result reflects the best of current British and mainland European practice.

Growth in clinical applications (and areas of controversy) is reflected by extended and well-referenced sections on EEG analysis, assessment of epilepsy for surgery, changes in practice in the investigation of certain paediatric disorders due to

increased understanding of their genetic basis, monitoring during surgery and intensive care and on magnetoencephalography. There are also balanced reviews of the use and abuse of techniques, training of staff and medico-legal issues together with advice on the setting up and running a department of clinical neurophysiology.

Although directed primarily towards clinical neurophysiologists, the text provides a comprehensive introduction to the subject for doctors and clinical scientists working in other disciplines and is also relevant to physiological measurement technologists working towards higher qualifications and to biomedical engineers involved in design of equipment.

The material that we present in this volume has been provided in good faith and is correct to the best of our knowledge. No one should undertake any of the techniques described without having undertaken adequate, recognised, training and without consulting up-to-date local, national and international regulations on safety and similar local, national and international recommendations on good practice.

We end on a sad note: it is with great regret that we have to announce that Professor Bernadette Bady of the Hôpital Neurologique in Lyon, who contributed much of the work on EMG in neonates and children, died during the making of this book.

CDB, RC, FM, JWO, PFP, BMT
March, 2003

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Abbreviations

AC	Alternating current
ACAS	Asymptomatic carotid artherosclerosis study group
ACI	Internal carotid artery
ACTH	Adrenocorticotrophin hormone
AD	Alzheimer's disease
A-D	Analogue to digital
ADAM	Advanced depth of anaesthesia monitor
ADEM	Acute disseminated encephalomyelitis
ADH	Antidiuretic hormone
ADHD	Attention deficit hyperactivity disorder
ADQ	Augmented delta quotient
AED	Anti-epileptic drug (therapy)
AEP	Auditory evoked potential
AIDP	Acute inflammatory demyelinating polyneuropathy
AIDS	Acquired immune deficiency syndrome
ALS	Amyotrophic lateral sclerosis
AMAN	Acute motor axonal neuropathy
AMP	Adenosine monophosphate
AMSAN	Acute motor sensory axonal neuropathy
ANN	Artificial neural network
AP	Action potential
AR	Auto regressive
AS	Active sleep
ASSD	Arginosuccinate synthetase deficiency
ATP	Adenosine triphosphate
AVM	Arterio-venous malformation
AWF	Airway flow
AWP	Airway pressure
BAEP	Brainstem auditory evoked potential
BBB	Blood brain barrier
BEAM	Brain electrical activity mapping
BCECTS	Benign childhood epilepsy with centro-temporal spikes
BECTS	Benign epilepsy with centro-temporal spikes
BETS	Benign epileptiform transients of sleep
BIS	Bispectral analysis/index
BNF	British National Formulary
BRAC	Basic rest and activity cycle
B-S	Burst suppression
C	Central (electrode site)
CA	Conceptual (conceptional) age
CABG	Coronary artery bypass graft (surgery)
CAE	Childhood absence epilepsy
CAP	Compound action potential
CAP	Cyclic alternating pattern
Cb	Cerebellar
CBF	Cerebral blood flow
CBF_{isi}	Initial slope index of CBF
CCT	Central conduction time
CD	Compact disc
CDSA	Colour density spectral array
CEA	Carotid endarterectomy
CEPOD	Confidential Enquiry into Perioperative Deaths
CFAM	Cerebral function analysing monitor
CFM	Cerebral function monitor
CH	Congenital hypomyelination
CHB	Complete heart block
CJ	Campylobacter jejuni
CJD	Creutzfeldt–Jakob disease
CLEMS	Congenital Lambert–Eaton syndrome
CMAP	Compound muscle action potential
$CMRO_2$	Cerebral metabolic rate for oxygen
CMRR	Common-mode rejection ratio
CMS	Congenital myasthenic syndrome
CMT	Charcot-Marie-Tooth disease
CMV	Cytomegalovirus
CN	Clinical neurophysiology
CNE	Concentric needle electrode
CN-EMG	Concentric needle EMG
CNS	Central nervous system
CNV	Contingent negative variation (potential)
COLD	Chronic obstructive pulmonary disease
CP	Cerebral palsy
CPAP	Continuous positive airway pressure
CPB	Cardiopulmonary bypass
CPP	Central perfusion pressure
CSA	Compressed spectral array
CSF	Cerebrospinal fluid
CSNB	Congenital stationary night blindness
CSWS	Continuous spike and wave during slow sleep
CT	Computerised tomography
CVA	Cerebral vascular accident
CVP	Central venous pressure
dB	Decibel
DBI	Diazepam binding inhibitor
DBS	Deep brain stimulation

DC	Direct current
DFT	Discrete Fourier transform
DIR	Double inversion recovery
DNA	Deoxyribonucleic acid
DNET	Disembryoplastic neuroepithelial tumour
DSA	Density spectral array
DSD	Dejerine Sottas disease
DSP	Digital signal processor
DST	Dexamethasone suppression test
DTI	Diffusion tensor imaging
DTL	Dawson–Trick–Litzkow (ERG electrodes)
DZ	Dizygotic
EA	Epileptiform activity
ECG	Electrocardiogram
ECI	Electrocerebral inactivity
ECN	Electroencephalography and clinical neurophysiology
ECochG	Electrocochleogram
ECoG	Electrocorticogram
ECS	Electrocerebral silence
ECST	European Carotid Surgery Trialists' Collaborative Group
ECT	Electroconvulsive therapy
EDS	Epileptiform discharges
EEG	Electroencephalogram, electroencephalograph, electroencephalography
EEMP	Electrically evoked muscle potential
EF	Evoked field (electrical, magnetic)
ELAE	Episodic low amplitude events
EMG	Electromyogram, electromyograph, electromyographic
ENT	Ear, nose and throat
EOG	Electro-oculogram
EP	Evoked potential
EPI	Echo planar imaging (MRI)
EPSP	Excitatory post-synaptic potential
ERG	Electroretinogram, electroretinographic
ERP	Event-related potential
ESES	Electrical status epilepticus during slow wave sleep
ESR	Erythrocyte sedimentation rate
F	Frontal (electrode site)
FC	Febrile convulsions
FCD	Focal cortical dysplasia
FDG-PET	F-deoxyglucose PET
FFT	Fast Fourier transform
FIM	Familial infantile myasthenia
FIRDA	Frontal intermittent rhythmic delta activity
FLAIR	Fluid attenuated inversion recovery
fMRI	Functional MRI
FO	Foramen ovale
FOLD	Female, Occipital, Lower (amplitude), Drowsy
f/s	Flashes per second
fT	Femto Tesla (10^{-15} Tesla)
FT	Fourier transform
GA	Gestational age
GABA	Gamma-amino butyric acid
Gb	Giga byte
GBS	Guillain–Barré Syndrome
GCS	Glasgow coma score
GOS	Glasgow outcome score
GSS	Gerstmann–Straussler–Scheinker syndrome
GTC/GTCS	Generalised tonic-clonic convulsions/seizures
GW	Gestational weeks
HF	High frequency
HIE	Hypoxic-ischaemic encephalopathy
HIV	Human immunodeficiency virus
HL	Hearing level
HMN	Hereditary motor neuropathy
HMSN	Hereditary motor and sensory neuropathy
HSAN	Hereditary sensory and autonomic neuropathy
HR	Heart rate
HRV	Heart rate variability
HV	Hyperventilation
Hz	Hertz, cycles per second (frequency)
IBI	Inter burst intervals
ICP	Intracranial pressure
ICSD	International classification of sleep disorders
ICU	Intensive care unit
IEC	International Electrochemical Commission
IED	Interictal epileptiform discharges
IEI	Intracranial electrode implantation
IFCN	International Federation for Clinical Neurophysiology
IFSECN	International Federation of Societies for Electroencephalography and Clinical Neurophysiology
IGE	Idiopathic generalised epilepsies
ILAE	International League Against Epilepsy
I/O	Input/Output (ports of computer)
IPI	Inter-peak interval
IPS	Intermittent photic stimulation
IRDA	Intermittent rhythmic delta activity
IT	Information technology
ITU	Intensive therapy unit
i.v. or i/v	Intravenous
IVH	Intraventricular haemorrhage
JAR	Joint aviation requirements (fitness to fly)
JMA	Juvenile myoclonic absence
JME	Juvenile myoclonic epilepsy

KSS	Kearnes–Sayre syndrome
kΩ	Kilohms
LAN	Local area network
LED	Light-emitting diode
LF	Low frequency
LIF	Latency-intensity function
LOC	Left outer canthus
LSP	Later significant patterns (ictal patterns later in a seizure)
LVI	Low voltage intermittent (irregular)
MAC	Minimum alveolar concentration
MAOI	Monoamine oxidase inhibitor
MAP	Mean arterial pressure
MAPB	Mean arterial blood pressure
MCD	Malformations of cortical development
MCV	Motor conduction velocity
MEG	Magnetoencephalograph, magnetoencephalogram, magnetoencephalography
MELAS	Mitochondrial encephalopathy with lactic acidosis and stroke-like episodes
MERRF	Myoclonus epilepsy with ragged red fibres
MFS	Miller Fisher syndrome
MLAEP	Middle latency auditory evoked potential
MLD	Metachromatic leucodystrophy
MMR	Measles, mumps and rubella (vaccination)
MN-SEP	Median nerve stimulation SEP
MRI	Magnetic resonance imaging
ms	Millisecond(s)
MS	Multiple sclerosis
MSI	Magnetic source imaging
MSLT	Multiple sleep latency test
MST	Multiple subpial transaction
MT	Movement time (during sleep)
MTR	Magnetisation transfer ratio
MTS	Mesial temporal lobe seizure epilepsy
MUAP	Motor unit action potential
MZ	Monozygotic
MΩ	Megohms
NAP	Nerve action potential
NASCET	North American Symptomatic Carotid Endarterectomy Trial Collaborators
NCEPOD	National Confidential Enquiry into Perioperative Deaths
NCLF	Neuronal ceroid lipofuscinosis
NCS	Nerve conduction studies
NEAD	Non-epileptic attack disorder
NES	Non-epileptic seizures
NESLEs	Non-epileptic seizure like events
nHL	Normal hearing level
NICU	Neonatal intensive care unit
NIRS	Near infra-red spectroscopy
NMDA	N-methyl-D-aspartite
NMR	Nuclear magnetic resonance
NP	Neurophysiological
NPT	Nocturnal penile tumescence
NREM	Non REM (of sleep)
O	Occipital (electrode site)
OAE	Otoacoustic emissions
OCTD	Ornithine carbamyl transferase deficiency
OIRDA	Occipital intermittent rhythmic delta activity
OSET	International Organisation of Societies for Electrophysiological Technology
P	Parietal (electrode site)
$PaCO_2$	Arterial blood carbon dioxide tension
PAO	Pattern at onset (ictal onset pattern)
PaO_2	Arterial blood oxygen tension
PAP	Positive airway pressure
PC	Personal computer
PCA	Post-conceptional (post-conceptual) age
PCM	Pulse code modulation
PCO_2	Carbon dioxide tension
PCP	Phencyclidine
PCR	Photoconvulsive response
PDA	Polymorphic delta activity
PDF	Probability density function
PDS	Paroxysmal depolarisation shifts
pEEG	Pharmaco-EEG
PET	Positron emission tomography
Pg	Pharyngeal
PGA	Post gestational age
PHB	Partial heart block
PHR	Photic high-frequency response
PKU	Phenylketonuria
PLEDs	Periodic lateralised epileptiform discharges
PLM	Periodic limb movements (in sleep)
PLP	Proteolipid protein
PMA	Post menstrual age
PMT	Physiological measurement technologist
PNS	Partial (parietal?) non-progressive stroke
POSTs	Positive occipital sharp transients (of sleep)
PPR	Photoparoxysmal response (prolonged photoconvulsive response)
PRSW	Positive Rolandic sharp waves
PSE	Porto-systemic encephalopathy
PTA	Post traumatic amnesia
PTN-SEP	Posterior tibial nerve stimulation SEP
PT	Premature temporal theta
PTSW	Posterior temporal sharp waves
PVL	Periventricular haemorrhage
PVS	Persistent vegetative state
QALY	Quality of life measurement unit
qEEG	Quantitative EEG
qpEEG	Quantitative pharmaco-EEG
QS	Quiet sleep

QUOL/ QOL	Quality of life
RAM	Random access memory
RBBB	Right bundle branch block
rCBF	Regional cerebral blood flow
REM	Rapid eye movement
RF	Radio frequency
RIND	Reversible ischaemic neurological deficit
rINN	Recommended international non-proprietary name (of drugs)
RLS	Restless legs syndrome
rms	Root mean square
ROC	Right outer canthus
ROM	Read only memory
SaO_2	Arterial oxygen saturation
SAP	Sensory action potential
SAP	Systemic arterial pressure
SAP	Systolic arterial pressure
SCBU	Special care baby unit
SD	Standard deviation
SEEG	Stereo EEG
SEF	Spectral edge frequency
SEF90	SEF marker at 90% of spectral range
SEM	Standard error of mean
SEMP	Sensory evoked muscle potential
SEP	Somatosensory evoked potential
SIDS	Sudden infant death syndrome
SLE	Systemic lupus erythematosis
SMA	Spinal muscular atrophy
SMN	Survival motor neurone (gene)
SMNc	Centromeric SMN
SMNt	Telomeric SMN
SNAP	Sensory nerve action potential
SNR	Signal to noise ratio
SOREM	Sleep onset REM
Sp	Sphenoidal
SPECT	Single proton emission computerised tomography
SPL	Sound pressure level
SQuID	Superconducting quantum interference device
SREDA	Sub-clinical rhythmic epileptiform discharge of adults
SSEP	Somatosensory evoked potential (= SEP)
SSPE	Subacute sclerosing panencephalitis
SSRIs	5-HT reuptake inhibitors
SSS	Small sharp spikes
STFT	Short time Fourier transform
SW	Spike and Wave
SWS	Slow wave sleep
T	Temporal (electrode site)
T	Tesla
TC	Time constant
TCD	Transcranial Doppler
TCI	Transitory cognitive impairment
$TcPO_2$	Transcutaneous oxygen tension
TIA	Transient ischaemic attack
TIRDA	Temporal IRDA
TLE	Temporal lobe epilepsy
TMS	Transcranial magnetic stimulation
TS	Tourette's syndrome
US	Ultrasound
V	Vertex (electrode site)
VDU	Video display unit
VEP	Visual evoked potential
VNS	Vagal nerve stimulation
WAN	Wide area network
WHAM	Waking (state), Higher (amplitude), Anterior, (common in) Men
8NAP	8th cranial nerve action potential

Contents