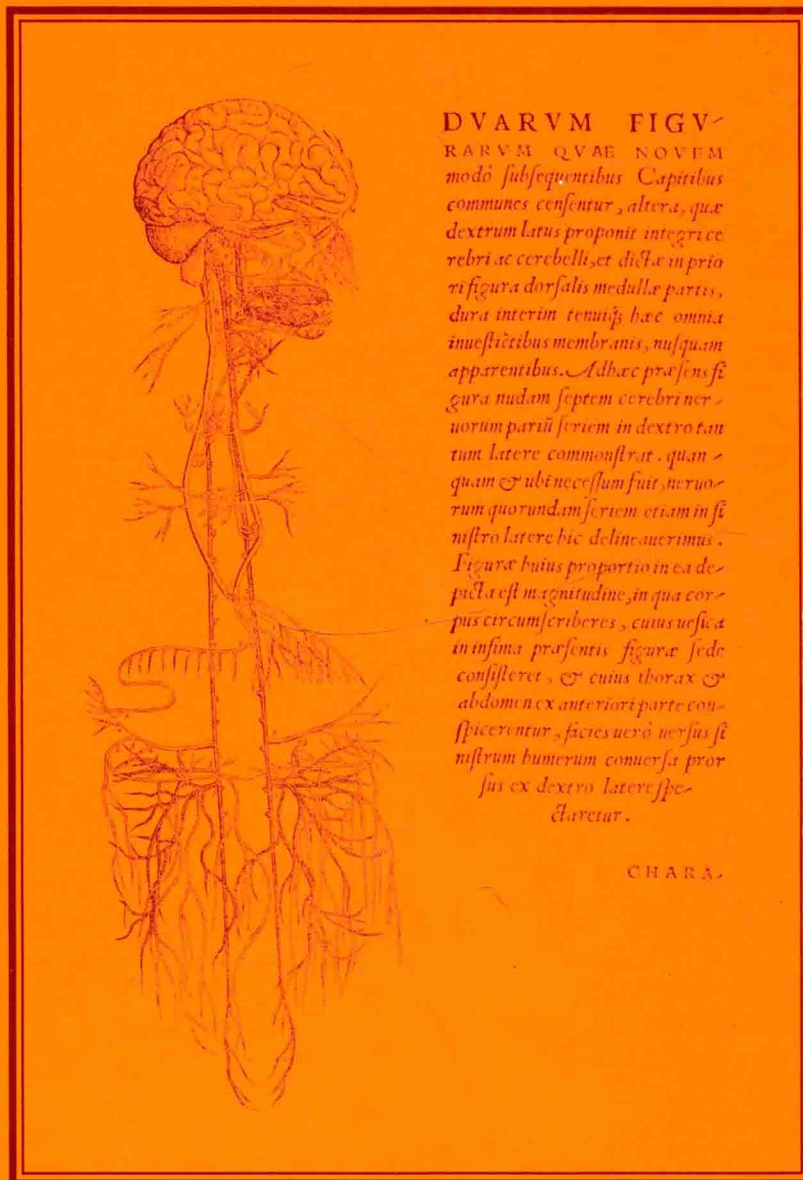


Clinical Neurophysiology, Volume 2

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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EEG, Paediatric Neurophysiology, Special Techniques and Applications

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Cover figure:

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 painter 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.

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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 Osselson *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	CAE	Childhood absence epilepsy
ACAS	Asymptomatic carotid arteriosclerosis study group	CAP	Compound action potential
ACI	Internal carotid artery	CAP	Cyclic alternating pattern
ACTH	Adrenocorticotrophin hormone	Cb	Cerebellar
AD	Alzheimer's disease	CBF	Cerebral blood flow
A-D	Analogue to digital	CBF _{isi}	Initial slope index of CBF
ADAM	Advanced depth of anaesthesia monitor	CCT	Central conduction time
ADEM	Acute disseminated encephalomyelitis	CD	Compact disc
ADH	Antidiuretic hormone	CDSA	Colour density spectral array
ADHD	Attention deficit hyperactivity disorder	CEA	Carotid endarterectomy
ADQ	Augmented delta quotient	CEPOD	Confidential Enquiry into Perioperative Deaths
AED	Anti-epileptic drug (therapy)	CFAM	Cerebral function analysing monitor
AEP	Auditory evoked potential	CFM	Cerebral function monitor
AIDP	Acute inflammatory demyelinating polyneuropathy	CH	Congenital hypomyelination
AIDS	Acquired immune deficiency syndrome	CHB	Complete heart block
ALS	Amyotrophic lateral sclerosis	CJ	Campylobacter jejuni
AMAN	Acute motor axonal neuropathy	CJD	Creutzfeldt–Jakob disease
AMP	Adenosine monophosphate	CLEMS	Congenital Lambert–Eaton syndrome
AMSAN	Acute motor sensory axonal neuropathy	CMAP	Compound muscle action potential
ANN	Artificial neural network	CMRO ₂	Cerebral metabolic rate for oxygen
AP	Action potential	CMRR	Common-mode rejection ratio
AR	Auto regressive	CMS	Congenital myasthenic syndrome
AS	Active sleep	CMT	Charcot-Marie-Tooth disease
ASSD	Arginosuccinate synthetase deficiency	CMV	Cytomegalovirus
ATP	Adenosine triphosphate	CN	Clinical neurophysiology
AVM	Arterio-venous malformation	CNE	Concentric needle electrode
AWF	Airway flow	CN-EMG	Concentric needle EMG
AWP	Airway pressure	CNS	Central nervous system
BAEP	Brainstem auditory evoked potential	CNV	Contingent negative variation (potential)
BBB	Blood brain barrier	COLD	Chronic obstructive pulmonary disease
BEAM	Brain electrical activity mapping	CP	Cerebral palsy
BCECTS	Benign childhood epilepsy with centro-temporal spikes	CPAP	Continuous positive airway pressure
BECTS	Benign epilepsy with centro-temporal spikes	CPB	Cardiopulmonary bypass
BETS	Benign epileptiform transients of sleep	CPP	Central perfusion pressure
BIS	Bispectral analysis/index	CSA	Compressed spectral array
BNF	British National Formulary	CSF	Cerebrospinal fluid
BRAC	Basic rest and activity cycle	CSNB	Congenital stationary night blindness
B-S	Burst suppression	CSWS	Continuous spike and wave during slow sleep
C	Central (electrode site)	CT	Computerised tomography
CA	Conceptual (conceptional) age	CVA	Cerebral vascular accident
CABG	Coronary artery bypass graft (surgery)	CVP	Central venous pressure
		dB	Decibel
		DBI	Diazepam binding inhibitor
		DBS	Deep brain stimulation

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

KSS	Kearnes–Sayre syndrome	NP	Neurophysiological
kΩ	Kilohms	NPT	Nocturnal penile tumescence
		NREM	Non REM (of sleep)
LAN	Local area network	O	Occipital (electrode site)
LED	Light-emitting diode	OAE	Otoacoustic emissions
LF	Low frequency	OCTD	Ornithine carbamyl transferase deficiency
LIF	Latency-intensity function	OIRDA	Occipital intermittent rhythmic delta activity
LOC	Left outer canthus	OSET	International Organisation of Societies for Electrophysiological Technology
LSP	Later significant patterns (ictal patterns later in a seizure)		
LVI	Low voltage intermittent (irregular)	P	Parietal (electrode site)
MAC	Minimum alveolar concentration	PaCO ₂	Arterial blood carbon dioxide tension
MAOI	Monoamine oxidase inhibitor	PAO	Pattern at onset (ictal onset pattern)
MAP	Mean arterial pressure	PaO ₂	Arterial blood oxygen tension
MAPB	Mean arterial blood pressure	PAP	Positive airway pressure
MCD	Malformations of cortical development	PC	Personal computer
MCV	Motor conduction velocity	PCA	Post-conceptual (post-conceptual) age
MEG	Magnetoencephalograph, magnetoencephalogram, magnetoencephalography	PCM	Pulse code modulation
MELAS	Mitochondrial encephalopathy with lactic acidosis and stroke-like episodes	PCO ₂	Carbon dioxide tension
MERRF	Myoclonus epilepsy with ragged red fibres	PCP	Phencyclidine
MFS	Miller Fisher syndrome	PCR	Photoconvulsive response
MLAEP	Middle latency auditory evoked potential	PDA	Polymorphic delta activity
MLD	Metachromatic leucodystrophy	PDF	Probability density function
MMR	Measles, mumps and rubella (vaccination)	PDS	Paroxysmal depolarisation shifts
MN-SEP	Median nerve stimulation SEP	pEEG	Pharmaco-EEG
MRI	Magnetic resonance imaging	PET	Positron emission tomography
ms	Millisecond(s)	Pg	Pharyngeal
MS	Multiple sclerosis	PGA	Post gestational age
MSI	Magnetic source imaging	PHB	Partial heart block
MSLT	Multiple sleep latency test	PHR	Photoc high-frequency response
MST	Multiple subpial transaction	PKU	Phenylketonuria
MT	Movement time (during sleep)	PLEDs	Periodic lateralised epileptiform discharges
MTR	Magnetisation transfer ratio	PLM	Periodic limb movements (in sleep)
MTS	Mesial temporal lobe seizure epilepsy	PLP	Proteolipid protein
MUAP	Motor unit action potential	PMA	Post menstrual age
MZ	Monozygotic	PMT	Physiological measurement technologist
MΩ	Megohms	PNS	Partial (parietal?) non-progressive stroke
		POSTs	Positive occipital sharp transients (of sleep)
NAP	Nerve action potential	PPR	Photoparoxysmal response (prolonged photoconvulsive response)
NASCET	North American Symptomatic Carotid Endarterectomy Trial Collaborators	PRSW	Positive Rolandic sharp waves
NCEPOD	National Confidential Enquiry into Perioperative Deaths	PSE	Porto-systemic encephalopathy
NCLF	Neuronal ceroid lipofuscinosis	PTA	Post traumatic amnesia
NCS	Nerve conduction studies	PTN-SEP	Posterior tibial nerve stimulation SEP
NEAD	Non-epileptic attack disorder	PT	Premature temporal theta
NES	Non-epileptic seizures	PTSW	Posterior temporal sharp waves
NESLEs	Non-epileptic seizure like events	PVL	Periventricular haemorrhage
nHL	Normal hearing level	PVS	Persistent vegetative state
NICU	Neonatal intensive care unit		
NIRS	Near infra-red spectroscopy	QALY	Quality of life measurement unit
NMDA	N-methyl-D-aspartate	qEEG	Quantitative EEG
NMR	Nuclear magnetic resonance	qpEEG	Quantitative pharmaco-EEG
		QS	Quiet sleep

QUOL/ QOL	Quality of life	SPECT	Single proton emission computerised tomography
RAM	Random access memory	SPL	Sound pressure level
RBBB	Right bundle branch block	SQuID	Superconducting quantum interference device
rCBF	Regional cerebral blood flow	SREDA	Sub-clinical rhythmic epileptiform discharge of adults
REM	Rapid eye movement	SSEP	Somatosensory evoked potential (= SEP)
RF	Radio frequency	SSPE	Subacute sclerosing panencephalitis
RIND	Reversible ischaemic neurological deficit	SSRIs	5-HT reuptake inhibitors
rINN	Recommended international non-proprietary name (of drugs)	SSS	Small sharp spikes
RLS	Restless legs syndrome	STFT	Short time Fourier transform
rms	Root mean square	SW	Spike and Wave
ROC	Right outer canthus	SWS	Slow wave sleep
ROM	Read only memory		
		T	Temporal (electrode site)
SaO ₂	Arterial oxygen saturation	T	Tesla
SAP	Sensory action potential	TC	Time constant
SAP	Systemic arterial pressure	TCD	Transcranial Doppler
SAP	Systolic arterial pressure	TCI	Transitory cognitive impairment
SCBU	Special care baby unit	TcPO ₂	Transcutaneous oxygen tension
SD	Standard deviation	TIA	Transient ischaemic attack
SEEG	Stereo EEG	TIRDA	Temporal IRDA
SEF	Spectral edge frequency	TLE	Temporal lobe epilepsy
SEF90	SEF marker at 90% of spectral range	TMS	Transcranial magnetic stimulation
SEM	Standard error of mean	TS	Tourette's syndrome
SEMP	Sensory evoked muscle potential		
SEP	Somatosensory evoked potential	US	Ultrasound
SIDS	Sudden infant death syndrome		
SLE	Systemic lupus erythematosus	V	Vertex (electrode site)
SMA	Spinal muscular atrophy	VDU	Video display unit
SMN	Survival motor neurone (gene)	VEP	Visual evoked potential
SMNc	Centromeric SMN	VNS	Vagal nerve stimulation
SMNt	Telomeric SMN		
SNAP	Sensory nerve action potential	WAN	Wide area network
SNR	Signal to noise ratio	WHAM	Waking (state), Higher (amplitude), Anterior, (common in) Men
SOREM	Sleep onset REM		
Sp	Sphenoidal	8NAP	8th cranial nerve action potential

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