European Manual of Medicine

Neurosurgery

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Training and Education

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2.1 Training in Neurosurgery

HANS-JÜRGEN REULEN

2.1.1 Introduction

National authorities and professional bodies have the responsibility for monitoring and recognising training institutions and to provide certification or recognition of medical specialists. The European Union of Medical Specialists (UEMS) is the responsible authority in the EU for harmonisation and improvement of the quality of training of medical specialists. Harmonisation is a necessary prerequisite to enable free movement of medical specialists in the countries of the EU.

The European Neurosurgical Training Charter of the UEMS [1] summarises the requirements and standards for training in neurosurgery. National organisations are strongly recommended to adopt these requirements in their national guidelines. In the following, all referrals are made to the European Neurosurgical Training Charter.

Departments in the process of developing or improving their training programme may find comprehensive information in *Training in neurosurgery in the countries of the EU, a guide to organize a training program* [2].

2.1.2 Goals of a Neurosurgical Training Programme

The main goal is to provide a trainee with a broad knowledge base, the necessary operative and procedural skills and experiences, as well as professional judgement as preparation for independent neurosurgical practice. Further goals are to teach self-criticism, critical assessment of his/her results, and the ability to undertake self-directed learning, which will eventually lead to continued expert practice and professionalism.

2.1.3 Length of Training

Neurosurgical training requires a minimum duration of six years which includes a minimum of four years training in clinical neurosurgery in an accredited programme. Of these four years at least three years should be spent in a UEMS member state and not less than three years in the same recognised programme. Training must include adequate exposure to intensive care and to paediatric neurosurgery. Because of the future reduction in the hours of work there may be a need to extend the training time in clinical neurosurgery from four to five years.

Up to a total of two years may be spent in related disciplines (in a surgical discipline, neurology, neuropaediatrics, neuroradiology, neuropathology, neurophysiology) and/or activities including research in neurosciences.

2.1.4 Contents of Training

The contents of training are described in the classical textbooks, encompassing knowledge in:

- General basics of surgery
- Complete neurological investigation tests and procedures
- Neurosurgical diseases, their diagnosis, prognosis, treatment indications, and their operative and non-operative treatment (including intensive care and possible complications)
- Conservative and operative treatment of head injuries and the spine/spinal cord
- Microsurgical operative techniques and neuronavigation
- Indications for and the interpretation of modern neuroradiological examination techniques (CT, MRI, myelography, angiography), as well as Doppler sonography and ultrasound
- Quality control (morbidity and mortality conference, infection control, risk management)

2.1.5 The Training Programme

- There should be a written *Training Curriculum* describing the contents and aims in each year of training. A structured *Surgical Training Plan* can be helpful to provide a systematic escalation of surgical competence and responsibilities. Emphasis should be placed on adequate time allocated for study and tuition independent of clinical duties.

- There should be established *Rotation Periods* covering all main areas of neurosurgery. Each rotation should have clearly defined goals with regard to responsibilities in patient care, knowledge and operative experience.
- During each rotation a trainee should be assigned to a specific trainer.
- There should be a documented *Education Programme* with lectures, clinical presentations, neuropathological and neuroradiological conferences, a journal club, a morbidity and mortality conference, teaching meetings including subspecialties, and teaching in ethics, administration, management and economics.
- It is recommended that trainees participate at least once a year in a national/European training course, in a hands-on course or a national neurosurgical meeting, respectively.
- Each trainee must keep an authorised *logbook* (meeting the standards of the UEMS/European Association of Neurosurgical Societies [EANS] logbook) for documentation of his/her operative experience. The trainee will have to demonstrate that he/she has assisted in a wide range of cases, which should include a balance of trainer-assisted and personal cases under supervision. The logbook must be supervised and signed regularly by the respective trainer, and it must be available at Board examination.
- Trainees should be encouraged to participate in research and to develop an understanding of research methodology. In academic programmes, clinical and/or basic research opportunities must be available to trainees with appropriate faculty supervision.

2.1.6 The Training Institution

A training institution must have national recognition in accordance with the standards of the UEMS Training Charter. Participation of training institutions in the European accreditation process at present is voluntary and, if compliant, indicates that the department and the training programme fulfil the European Standards of Excellence for Education in Neurosurgery.

Units that cannot comply with the minimum standards of the UEMS Training Charter (case volume and mixture, number of trainers and beds, etc. as listed below) and cannot offer the full spectrum of neurosurgery cannot be training centres on their own. It is recommended that they develop a common training programme in cooperation with a larger department. Highly specialised centres can be included in the rotation of a recognised training centre.

2.1.6.1 Requirements for Training Institutions with Regard to Equipment and Educational Facilities

- There must be a referral base sufficient to provide an adequate case volume and mixture to support the training programme.
- There must be a minimum of four trainers (including the chairman/programme director).
- There must be at least 30 neurosurgical beds and in addition critical care beds (7–10/million population).
- There must be at least two designated, fully staffed operating theatres (neurosurgically trained staff), appropriately equipped and with 24-h availability.
- There must be an operating microscope with CCTV for each theatre. The following are deemed essential equipment: ultrasonic aspirator, image guidance and/or ultrasound, a stereotactic system, radiological imaging, and endoscopy equipment.
- Neurosurgical theatres should be covered by anaesthetists with a special interest in neuroanaesthesia. Anaesthesia coverage should be available at all times for neurosurgery.
- There must be designated and fully staffed neurosurgical intensive care beds. Neurosurgical intensive care may be managed by neurosurgery or there may be joint responsibility between neurosurgery and anaesthesia.
- There must be an emergency unit with 24-h admission.
- There must be outpatient clinics where non-emergency patients are seen before and after surgery.
- There must be exposure to paediatric neurosurgery as a mandatory component of a training programme. Where this does not form part of the routine work of a neurosurgical department, a 6-month secondment to an appropriate programme should be arranged (It must be recognised that in some European countries paediatrics requires special training and a protected environment).
- There should be opportunity to obtain experience in functional neurosurgery either within the department or in another neurosurgical department specialising in this field.
- All main specialities (neurology, surgery/traumatology, anaesthesiology, radiology, neuroradiology, neuropathology, radiotherapy, internal medicine, paediatrics) must be present to provide the trainee with the opportunity of developing his/her skills in a team approach to patient care.
- There should be an easily accessible library, with an adequate selection of books and journals on neurosurgery, as well as facilities for computer literature searches.

2.1.6.2 Institutional Quality Management Provisions

A training institution must have an internal system of quality assurance. There should be written guidelines concerning patient care and patient information (patient's consent), referrals, medical records, documentation, on-call and back-up schedules, days off, residents' working schedules, attendance at conferences and educational activities). An example may be found in [2]. There must be a structured procedure for the reporting of adverse events in the form of a mortality and morbidity conference; and the hospital should have an infection control committee and a drugs and therapeutics committee.

2.1.6.3 Responsibilities of a Training Programme Director

The training programme director does not need to be the head of the training institution. He/she must be a certified specialist of a minimum of five years, and demonstrate evidence of continuing professional development.

The Programme Director must establish a transparent and fair appointment process for trainees. A training agreement (contract) should be completed and signed by the director and the trainee at the beginning of training. The programme director should provide the trainee with a written *Training Curriculum* of his/her training (see Sect. 2.1.5). The promotion of an ethos of a high level of professional conduct and ethics within the training programme is essential.

The programme director has to:

- Organise and coordinate a balanced training programme with established rotations ensuring that the trainee will have exposure to all aspects of neurosurgery. The programme must be written and available to trainees and trainers.
- Ensure that there is dedicated time allocated to the trainers for training and that the trainers fulfil their training responsibilities.
- Ensure that there is dedicated time for trainees to attend educational meetings and approved courses, and that trainees can fulfil all training obligations.
- Ensure that the individual trainee's documentation (training portfolio) is up to date.
- Organise a transparent and fair semi-annual progress evaluation of trainees.
- Provide valid documentation as to satisfactory completion of training.

2.1.6.4 Responsibilities of Trainers

Trainers should be certified specialists and possess the necessary administrative, teaching and clinical skills, and commitment to instruct and support their trainees. They have to:

- Set realistic aims and objectives for a rotation period
- Supervise the day-to-day work of the trainee on the ward, in the outpatient clinic and in the operating theatre
- Support the trainee's operative and clinical progress and provide feedback
- Assess and report on the trainee's progress at the end of each rotation (progress evaluation)
- Inform the programme director of problems at an early stage

2.1.6.5 Requirements for Trainees

- Trainees during their training must be exposed to at least four different trainers and the full spectrum of neurosurgical procedures.
- The attached Operative List (Appendix 1) summarises the minimal and optimal numbers of so-called key procedures that trainees should have performed on completion of training. In addition to this mandatory list of operative procedures, the trainee should have assisted in or partly performed operations for pituitary adenomas, complex basal meningiomas, aneurysms, arteriovenous malformations, acoustic neurinomas, paediatric procedures, intramedullary tumours, etc. (see assistant figures in Appendix 1) [3].
- Trainees should be directly involved in the pre- and postoperative management of these patients and should have a detailed understanding of the preoperative investigations.
- Many of the above procedures demand the use of the operating microscope that the trainee must be fully familiar with.
- The trainee must learn to record and document patient history, examinations and investigative findings, obtain patients' consent for operative procedures, clearly detailing the reasons for performing the procedure and the risks involved, as well as learn to communicate with patients and relatives and pass on distressing information (e.g. malignancies or bereavement) in a sensitive and caring manner.
- He/she must maintain an operative logbook detailing his/her involvement in all cases. He/she should ensure that the goals and objectives of each rotation are met, that all problems are discussed with the assigned trainer and that copies of the progress evaluation forms are stored. Also it is recommended to keep a record of courses attended, publications and/or presentations (training portfolio).

- A neurosurgical training record (Appendix 2) lists the cumulative operative experiences done by a trainee and shows the 'competence level' of each procedure expected at the end of training [4]. On completion of training the trainee tabulates his/her cumulative operative totals and indicates his/her level of competence. The training director certifies an adequate competency level for each procedure by signing the training record.

2.1.7 Periodic Progress Evaluation

Periodic evaluation at 6-month intervals or at the end of a rotation period is an objective and fair instrument to ensure that trainees progress satisfactorily throughout the training. The logbook is used as supporting documentation. The trainer produces a written summary, using a structured format (Trainee Evaluation Form), and discusses with the trainee whether:

- Agreed goals have been met during the past rotation
- Specific knowledge, operative totals and all other aspects of training have been reached
- Any weak areas have been identified that require intensified supervision, advice and support. Failure to meet the agreed target must be brought to the attention of the training programme director.

In addition, the further development of training should be discussed and aims and objectives for the next rotation may be formulated. The Evaluation Sheet must be signed by the trainer/programme director and trainee and kept in the trainee's portfolio.

In future a separate (anonymous) evaluation of their training by the trainees may become helpful to receive the feedback of the trainees concerning clinical and operative training, teaching, supervision and support, feedback of progress and career advice.

2.1.8 Certification at Completion of Training

An application for certification as a specialist must be sent to the national authority responsible for recognition/certification as a medical specialist. The application must include:

- Details of previous training posts, including dates, duration and trainers
- Satisfactory cumulative operative totals performed by the trainee (logbook and operative list)
- Signed Progress Evaluation Forms for each rotation/training period
- List of training courses attended, hands-on courses, meetings, etc.
- Letter from the programme director providing valid documentary evidence of the satisfactory completion of training
- Specific additional requirements may exist in individual countries (list of publications, list of presentations at meetings, reviews, expert opinion, etc.)

Many countries in Europe now have a compulsory written (MCQ) and oral examination, with the majority having an oral board examination. At present the level of such examinations varies considerably, and a common standard is needed urgently. It should be underlined that the EANS/UEMS offers a written and oral European Board Examination of high standard twice a year. Countries that do not have a full board examination in place may use the European written and/or oral examination as an equivalent, or organise their national examination with the support and advice of the EANS/UEMS Examination Committee.

2.1.9 Subspecialisation

Competence in complex procedures exceeding the knowledge and operative totals required at the end of training can be developed after completion of training within the framework of a 12- to 18-month subspecialisation fellowship. The definition and organisation of subspecialisation is presently being discussed in a UEMS/EANS committee and will be published in *Acta Neurochirurgica*.

Appendix 1

The New Operative Figures for Trainees

Key Procedures

In order to make neurosurgical training comparable in the various European countries, key procedures have been defined. Every trainee at the end of training should be able to perform these procedures independently, i. e. with a trainer supervising but not making a significant decision/practical manoeuvre during the operation. The list is detailed and ensures that a trainee has acquired broad operative experience (Appendix 1). With these key procedures, a certain standard of training is guaranteed and in future will become more and more important as subspecialty areas are developed.

Societies may wish to include additional key procedures and certainly can do so.

Minimum and Optimum Figures

Minimum figures should be attained. It is of great importance that within the specific categories the trainee acquires sufficient experience. If the minimum of one key procedure is not fully met, this can be counterbalanced by a comparable key procedure of the same area. The minimum operative total for each area should be attained.

The optimum figures are provided as a goal for a good training programme and also to allow for competency-based training. It takes into account that trainees progress at varying rates. For some operations only 'optimum' figures are indicated. National societies may define such operations as key procedures.

If minimum figures are not achieved, smaller departments may need to arrange a rotation of their trainees for part of their training with larger departments.

Assistant Figures

For many years, opinions among trainers have differed considerably as to whether each trainee should have performed complex operations personally, such as aneurysms, AVMs, acoustic neuromas, spinal intramedullary tumours, basal meningiomas, brain tumours in children, etc. To solve this problem, a separate list of assistant figures is included (Appendix 1, assistant figures). This list contains procedures that trainees have to assist in or perform in part but with no obligation to perform them personally/independently. Most of these procedures will be learned either after finishing residency or in a subsequent subspecialty programme. The requirement of the assistant figures ensures that trainees are exposed to such complex diseases during their training and become familiar with the diagnostic procedures, the treatment options and the follow-up required. The specified minimum figures should be attained.

Appendix 1 Neurosurgical Training Requirements – Adults[a]

			Operative totals	
			Minimum	Optimum
1.	Head injuries	Total	47	93
	Burr holes: external ventricular drainage/ICP monitoring/reservoir		15	30
	Chronic subdural haematoma		10	20
	Craniotomy: extradural/subdural/intracerebral haematoma/contusions		10	20
	Depressed skull fracture		5	8
	Dural repair (CSF fistula)		2	5
	Cranioplasty		5	10
2.	Supratentorial tumours and lesions (excluding stereotactic procedures)	Total	40	61
	Intrinsic tumours: primary/metastatic		30	40
	Meningioma		8	12
	Pituitary adenoma (transsphenoidal/transcranial)		0	5[b]
	Other benign lesions (epidermoid, arachnoidal cyst, etc.)		2	4
3.	Posterior fossa lesions	Total	7	14
	Primary and metastatic tumours		3	6
	Chiari malformation/posterior fossa decompression		2	4
	Other benign lesions (epidermoid, arachnoidal cyst, von Hippel-Lindau, etc.)		2	4

[a] It is of great importance that within the specific areas there is sufficient experience. If the minimum of one key procedure is not fully met, it can be counterbalanced by a comparable key procedure of the same area. The minimum operative total of each area should be attained

[b] For some operations only 'optimum' figures are given. Some national societies may define such operations as key procedures

[c] In a few European countries peripheral nerve procedures have, in the past, not been a mandatory requirement

Appendix 1 Neurosurgical Training Requirements – Adults[a]

			Operative totals	
			Minimum	Optimum
4.	**Infection (cranial/spinal)**	Total	8	12
	Abscess/subdural empyema		8	12
5.	**Vascular**	Total	10	27
	Craniotomy: aneurysm		0	8[b]
	Craniotomy: arteriovenous malformations (AVM)		0	2[b]
	Cavernous angioma		2	5
	Haematoma (spontaneous intracerebral/intracerebellar)		8	12
6.	**Hydrocephalus (≥ 16 years)**	Total	42	69
	Shunting procedure, initial		20	30
	Shunt revision		10	15
	Endoscopic fenestrations		2	4
	External ventricular drainage		10	20
7.	**Spine**	Total	92	145
	Cervical disc disease/spondylosis: anterior decompression/foraminotomy		15	25
	Cervical instrumentation (anterior/posterior)		3	5
	Lumbar disc disease/spondylosis: lumbar disc		50	70
	Laminotomy/laminectomy for spondylosis		10	15
	Lumbar instrumentation		5	10
	Spinal tumours: extradural		3	5
	Spinal tumours: intradural extramedullary		3	5
	Spinal tumours: instrumentation in vertebral tumours		0	5[b]
	Spinal trauma: decompression/instrumentation		3	5
8.	**Trigeminal and other neuralgias**	Total	7	13
	Injection techniques/radiofrequency lesion		5	8
	Microvascular decompression		2	5
9.	**Stereotactic and functional neurosurgery**	Total	5	23
	Stereotactic tumour biopsy		5	10
	Surgery for epilepsy		0	3[b]
	Therapeutic electrostimulation (peripheral nerve, spinal)		2	5[b]
	Implantation of ports/pumps for intrathecal drug delivery		2	5[b]
10.	**Peripheral nerve[c]**	Total	30	45
	Entrapment decompression/transposition		30	45
11.	**Computer-aided interventions (not the procedures)**	Total	10	25
12.	**Basic techniques**	Total		
	Craniotomy supratentorial		60	80
	Craniotomy posterior fossa		8	20

[a] It is of great importance that within the specific areas there is sufficient experience. If the minimum of one key procedure is not fully met, it can be counterbalanced by a comparable key procedure of the same area. The minimum operative total of each area should be attained

[b] For some operations only 'optimum' figures are given. Some national societies may define such operations as key procedures

[c] In a few European countries peripheral nerve procedures have, in the past, not been a mandatory requirement

Appendix 1 Neurosurgical Training Requirements – Paediatric through 15 Years of Age

			Operative totals	
			Minimum	Optimum
1.	**Hydrocephalus and congenital malformation**	**Total**	**7**	**15**
	External ventricular drainage		5	10
	Shunting procedure		2	5
2.	**Head and spine injuries**	**Total**	**0**	**10**
	Burr holes: ICP monitoring/drainage/reservoir		0	5[a]
	Chronic subdural haematoma/hygroma		0	2[a]
	Extradural/subdural haematomas		0	3[a]
3.	**Brain tumours and lesions**	**Total**	**0**	**3**
	Supratentorial tumours		0	3

[a] For some operations only 'optimum' figures are given. Some national societies may define such operations as key procedures

Appendix 1 Neurosurgical Training Requirements – Assistant Figures

Procedure	Number
Craniopharyngioma	5
Pituitary adenomas (transsphenoidal + transcranial)	10
Acoustic neurinoma	10
Complex basal/posterior fossa meningioma	10
Craniotomy: aneurysm	12
Craniotomy: AVM	5
Occlusive: endarterectomy	3
Thoracic disc disease	3
Spinal tumours: intramedullary	3
Thalamotomy, pallidotomy/stimulation technique	5
Implantation of ports/pumps for intrathecal drug delivery	5
Single suture craniosynostosis	2
Paediatric infratentorial tumours	2
Meningocele/meningomyelocele	3
Tethering syndromes	2
Spinal dysraphism	2
Peripheral nerve sutures (with graft)[a]	3

[a] In a few European countries peripheral nerve procedures have, in the past, not been a mandatory requirement

Appendix 2

Neurosurgical Training Record

	Nature of operation – Adults	T Operative Totals			Minimum Competency level end of 6th Year			Training Director's signature
1.	**Head Injuries**	T	TS	A	1	2	3	
	Burr holes ext. ventricular drainage /ICP-monitoring/reservoir							
	Chronic subdural haematoma							
	Craniotomy -extradural/subdural/intracerebral haematoma/ contusions							
	Depressed skull fracture							
	Dural repair (CSF fistula)							
	Cranioplasty							
2.	**Supratent.Tumours + Lesions (excl. stereotactic procedures)**							
	Intrinsic tumours – primary / metastatic							
	Meningioma – vault							
	Meningioma – parasagittal							
	Meningioma – complex basal							
	Pituitary adenoma (transphen. – transcranial)							
	Craniopharyngioma							
	Other benign lesions (epidermoid, arachnoidal cyst, etc.)							
3.	**Posterior Fossa Lesions**							
	Primary and metastatic tumours (cerebellar hemisphere)							
	Arnold Chiari malformation/ Posterior fossa decompression							
	Acoustic neurinoma							
	Other benign lesions (epidermoid, arachnoidal cyst, H. Lindau, etc.)							
4.	**Infection (cranial – spinal)**							
	Abscess / subdural empyema							
5.	**Vascular**							
	Craniotomy Aneurysm							
	Craniotomy AVM							
	Cavernous angioma							
	Haematoma (spontaneous intracerebral/intracerebellar)							
	Carotid endarterectomy							
6.	**Hydrocephalus (≥ 16 years)**							
	Shunting procedure, initial							
	Shunt-revision							
	Endoscopic fenestrations							
	External ventricular drainage							

	Nature of operation – Adults	T Operative Totals			Minimum Competency level end of 6th Year			Training Director's signature
7.	**Spine**	**T**	**TS**	**A**	**1**	**2**	**3**	
	Cervical disc disease/Spondylosis: anterior decompr./foraminotomy						■	
	Cervical instrumentation (anterior/posterior)					■		
	Lumbar disc disease/ Spondylosis: lumbar disc						■	
	– laminotomy/laminectomy for spondylosis						■	
	– lumbar instrumentation					■		
	Thoracic disc disease				■			
	Spinal Tumours: Extradural						■	
	– Intradural extramedullary					■		
	– Intradural intramedullary				■			
	– Instrumentation in vertebral tumours				■			
	Spinal Trauma: Decompression/Instrumentation					■		
8.	**Trigeminal and other Neuralgias**							
	Injection techniques/RF-lesion					■		
	Microvascular decompression					■		
9.	**Stereotactic and Functional Neurosurgery**							
	Stereotactic tumour biopsy						■	
	Thalamotomy, Pallidotomy/Stimulation technique				■			
	Surgery for epilepsy				■			
	Therapeutic electrostimulation (peripheral nerve, spinal)					■		
	Implantation of ports/pumps for intrathecal drug delivery						■	
10.	**Peripheral Nerve**							
	Entrapment decompression/transposition						■	
	Peripheral nerve sutures (with graft)				■			
11.	**Computer-aided interventions (not the procedures)**							
12.	**Basic Techniques**							
	Craniotomy supratentorial						■	
	Craniotomy posterior fossa						■	
	Transsphenoidal approach					■		

Definitions: T = The trainee has done the operation. The supervising consultant must not have made a decision/practical manoeuvre significantly affecting the execution of the operation.
TS = The trainee has done the operation but the supervising consultant has made a significant decision/practical manoeuvre during the operation.
C = The trainee has performed component parts during the operation under supervision of a senior surgeon: positioning, operative approach (i.e. craniotomy, opening) closure, drainage, draping, instructions for postoperative care.
A = The trainee is the principal assistant during the operation.

Competency levels: 1 = should have assisted in, but is unable to perform the procedure
2 = competent to perform procedure under direct supervision
3 = competent to perform procedure without direct supervision

Operative totals – Paediatric through 15 ys	Operative Totals			Competency levels end of 6th year			Training director's signature
1. Hydrocephalus and Congenital Malformation	T	TS	A+C	1	2	3	
External ventricular drainage							
Shunting procedure:							
Meningomyelocele							
Tethering syndromes							
Spinal dysraphism							
2. Head and Spine Injuries							
Burr holes, ICP-monitoring/drainage/reservoir							
Chronic subdural haematoma/hygroma							
Extra-/subdural haematoma							
3. Supra- and/or infratentorial tumours and lesions							
Supratentorial and/or infratentorial tumours							

Definitions: T = The trainee has done the operation. The supervising consultant must not have made a decision/practical manoeuvre significantly affecting the execution of the operation.
TS = The trainee has done the operation but the supervising consultant has made a significant decision/practical manoeuvre during the operation.
C = The trainee has performed component parts during the operation under supervision of a senior surgeon: positioning, operative approach (i. e. craniotomy, opening) closure, drainage, draping, instructions for postoperative care.
A = The trainee is the principal assistant during the operation.

Competency levels: 1 = should have assisted in, but is unable to perform the procedure
2 = competent to perform procedure under direct supervision
3 = competent to perform procedure without direct supervision

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2.2 Basic Training in Technical Skills: Introduction to Learning 'Surgical Skills' in a Constructive Way

JENS HAASE

That one, when in truth shall succeed in bringing a man to a destination, first and foremost you have to be careful to find him where he is and start from there. This is the secret of all art of assistance, and anyone who cannot understand this is conceited when he thinks that he can help others.

(Fragment of a straightforward message: Danish philosopher, Soren Kierkegaard 1856)

2.2.1 Introduction to 'Basic Training Skills'

What is a good surgeon? This question cannot be easily, sincerely or precisely answered despite the fact that we 'all know' [54]. I assume that we all agree that a surgeon needs manual dexterity. Dexterity usually refers to skills and ease in physical activity especially manual activity which in the context of surgical dexterity should be understood as motor skills [1, 16]. Dexterity is closely connected to performance in surgery although a strict definition is not obtainable [46, 54].

Conventional surgical teaching is a daily working relationship between experienced teachers and trainees [6]. A young MD's training has been described as an opportunity to have access to patients, but experience as such, without training, increases only confidence and not competence [14]. Traditional teaching makes steep learning curves take place during interaction with real patients. This is not acceptable in modern societies as we know that the first surgical procedures performed by an inexperienced surgeon carry greater risks for the patient and often even unacceptable risks [11].

We have therefore tried to establish different methods of learning surgical skills such as manual dexterity.

2.2.2 Learning: Theories

Concerning learning and teaching, the so-called instructional approach has become synonymous with effective cognitive growth = learning [8].

Teaching neurosurgical skills today must be based on the concept: not to teach, but to facilitate learning and development of the abilities the trainee possesses.

Much surgical experience consists of procedural knowledge in the form of perceptual-motor or spatial skills that cannot be expressed verbally or in writing [49]. How we shall function in a microsurgical brain habitat teaches us that we must learn the true three-dimensional (3D) anatomy of the brain and not rely on simple pictures in our books. By spatial training in 3D models we learn where this anatomy is within the skull enhancing our chances of finding our designated targets more safely without complicated neuronavigation [20].

Learning in general is also tied to the motivation of the trainee, and effective learning of surgical skills depends on creating the right environment for learning. We have to accept that learning is connected with mental and emotional growth in which information access plays only a subordinate role [31].

Learners = trainees should therefore be viewed as active constructors rather than passive recipients of knowledge. In modern learning sciences, learning is a construct of the trainee's 'personality' and of the surroundings in which the trainee functions.

It has been documented that surgeons need a certain psychological and personal profile in order to become true experts in their field, as is the case with world-class athletes. Unless surgeons are prepared to learn and hence develop professionally, all training is doomed. The teacher's role is merely to support. In this 'enzymatic' way they facilitate the learner in the process of 'learning' [37]. It is therefore nowadays also accepted that even the teachers need to learn to perform as teachers [6].

We must ask ourselves these questions:

- How do we learn?
- What is the purpose of this for me?

These philosophical questions bring us far away from the concept of surgery. The Dreyfus brothers [14] argue that learning can be seen as a stepwise development through five stages. Briefly summarised these are as follows:

1. *Novices* act on the basis of context-independent elements and rules.
2. *Advanced beginners* begin to take account of situational factors, which they have learned to identify and interpret on the basis of their own experience from similar situations.

3. *Competent performers* are characterised by the involved choice of goals and plans as a basis for their actions. Goals and plans are used to structure and store masses of both context-dependent and context-independent information.
4. *Proficient performers* identify problems, set goals and plan intuitively from their own experientially based perspective, and these choices are checked by analytical evaluation prior to action.
5. *Experts* whose behaviour is building on intuitive, holistic and synchronic judgements in a way that, in a given situation, releases an adequate picture of the problem together with goal, plan, decision, and action in one instant and with no division into phases. This is the level of true human expertise. Experts are therefore characterised by a flowing, effortless performance, unhindered by analytical deliberation.

To these you may add a sixth level:

6. *Innovator experts:* Here we find persons who also understand the necessity of a debriefing session after a performance in order to consider the adequacy of old skills in order to develop new ones. In this way these experts become true innovators of new techniques.

Classical 'information feeding' of declarative knowledge will never take us above the first level of proficiency, i. e. novices. Information is NOT knowledge!! It is an error to assume that possessing a vast quantity of information is the same as having knowledge and understanding. Every 6–8 years our scientific knowledge has doubled! In a setting where more trainees must learn more and more in less and less time, this places an unrealistically high burden on the teachers and is a rather cost-intensive way of teaching.

From the second level on, the learning development depends on practical training, and in this process, declarative knowledge only supports the learning development up to the third, or perhaps fourth, level. It is therefore a prerequisite for the trainee to have a personal goal for the learning per se. Based on that, he/she has to develop a subset of tasks to be rehearsed. This learning is a group-monitored and group-oriented process and not a simple 'result-oriented' task [12, 20, 21]. The 'lonely wolf' training, which has been the standard set up in medicine for many years, is outdated. A prerequisite for making declarative choices is that the trainee learns to make the decision that seems 'right', that the trainee does not seek power over other trainees and that a disappointing result of a training session is considered a sign of a 'failure of the training process' and not a personal failure of the trainee [4, 9, 22, 44, 49].

Neurosurgeons have learned to be independent, and therefore tend to be very individualistic – which makes it difficult for most physicians to work together in a cooperative situation or in practice. (James I. Ausmann 1997)

By organising the surgical performance teaching in a structured systematic system based on problem-based learning and by introducing virtual reality (VR) learning methods, we can enhance speed and effect of learning basic dexterity and visualisation skills needed to perform surgery at the expert level [3, 23, 54].

It is well known that pilots are tested for both abilities and for psychological behaviour before they are introduced into a training programme. The same should perhaps also be a natural part of any surgical training programme [3, 40].

2.2.3 Length of Training Periods

Learning automatic dexterity = procedural memory, also means that we must learn these skills in a continuous manner. Although much surgical interference during an operation depends on declarative knowledge in terms of solid background knowledge of anatomy, physiology, pathology and surgical techniques and procedures, the 'true' surgical performance is significantly a procedural knowledge of 'knowing how' [15, 20, 37]. Procedural memory is stored in the cerebellum and basal ganglia. All training aimed at obtaining this procedural knowledge must be tailored to this fact.

The performance of a motor function is through reaction in the premotor and motor centres of the brain. In addition we have the supplementary motor area (SMA) on the mesial part of the frontal lobes where we visualise our movements. We can literally think of a specific movement, visualise it (without performing it) and see this SMA area light up on functional imaging [18]. In surgery our movements should be as automatic as they are when we are writing with a pen or riding a bicycle. It is further shown that training the non-dominant hand leads to a higher performance increase. Non-dominant left-hand stimulation also increases 3D space observation. Therefore rehearsal of movements via SMA and with the left hand may be of benefit for surgeons [41]. As Merleau-Ponty points out: 'A movement is learned when the body has understood it, that is, when it has incorporated it into its "world", and to move one's body is to aim at things through it; it is to allow oneself to respond to their call, which is made upon it independently of any representation.' [14]. Learning to play a piano from simple notes (procedural knowledge) and in a standard fashion can be achieved in 5–7 weeks by continuous training. This procedural skill of playing the piano stays with you for life and the novice can proceed in the learning from there.

This also means that we can learn movements or tasks by visualising them without being in a real operating theatre. Studies suggest that humans may form internal models of these primitive movements, which they can combine into more complex tasks. So when a task is broken down and learned in simple steps, rather than 'all at once', learning a complex task can be faster, and even performance improves [35, 36, 40]. One dexterity skill, which is often used, is moving a curved needle precisely along its own form. You may rehearse this in the air or through a piece of rubber or cloth, not necessarily through a human vessel or a rat vessel [39].

From our own microsurgical learning system at the Microsurgical Laboratory at Aalborg University Hospital, we have realised that it takes around 400 h of microsurgical training, from scratch, to be able to carry out, for example, a free flap transfer on a rabbit. When spending 8 h daily rehearsing in the laboratory, this means that it takes at least 50 days of training to become fully educated! Not 24 h as is the standard of a hands-on course.

2.2.4 Magnification of Surgical Dexterity

Competence in surgery depends on a plethora of factors and skills, and one among these is to perform surgery with the aid of the microscope, i. e. with magnification [44, 46]. When introduced to endoscope techniques, these are so different from daily life dexterities that all trainees understand the necessity for learning to use the endoscope before carrying out endoscope operative procedures on patients [17, 19, 29, 49]. For neurosurgeons the use of the microscope is nowadays essential; however it is often thought of being a simple tool for surgery, a tool that needs no 'training' to be used [5, 35]. This is a grave mistake.

Microsurgical techniques are specific tasks carried out in a specific microenvironment, a microhabitat created by the operative microscope [24]. Therefore our goal settings include performance using specific microsurgical instruments in this habitat, a task that demands a better understanding of the microscope. The microsurgical habitat lacks definition of sizes, which gives rise to perceptual problems in training [13]. The operative microscope has an enormous effect on surgical performance as it offers excellent light at the surgical stage under all circumstances with preservation of true 3D imaging, in contrast to endoscope surgery. The lenses of modern microscopes are of outstanding quality so that the images we receive at our retinas are perfect.

For microsurgery the surgeon needs to be able to control hand/finger tremor at the micro level and to master changed hand–eye coordination with angles rotated and distances magnified by the microscope. The learning of microsurgical techniques or skills requires the surgeon to learn to work in a microsurgical environment using and understanding microsurgical instruments serving as interfaces between hand/brain and the target.

When the surgeon becomes familiar with a new tool (instrument), this tool will become 'internalised', forming a 'functional organ' together with the surgeon's hand [28]. While the two terms 'tool' and 'interface' are far from having identical meanings, the tool can thus now be thought of as an interface between the holistic surgeon and the object (e.g. the patient that is to be operated on). However, in this process of internalisation of the microsurgical instruments, the surgeon has to develop specific skills in order to use the tool. The surgeon must also learn to control the behaviour of tissues and threads involved.

Despite the fact that microscopes have been on the market for more than 35 years, surgeons still forget the simple adjustments of these instruments, most pronounced in the continuous balancing of the microscope. In modern microscopes, this balancing is constant despite the position of any part of the microscope. Movements are augmented server driven in some, which decreases the muscle power needed to adjust the position and thereby reduces fatigue and tremor [26]. The surgeon that grabs the microscope and some microsurgical instruments and trusts that he/she can carry out the microsurgical procedure has not fully understood this paradigm, and disasters will follow.

Experiments have shown major differences in touch sensing among inexperienced and experienced surgeons/students [10] documenting this problem. For accurate control the trainee must develop new motor strategies involving only the fine motion of the fingers [18]. Arm movements used in macrosurgery induce too much tremor. The overwhelming use of the operative microscope's 'zoom function' delays the learning of micro sizes and thereby our functionality in the micro space. If we position a structure of known size in the operative training field this could facilitate the understanding of sizes. What is the length of the tip of an instrument? Measure it, watch it using the microscope with variable magnification and it will help to develop these skills of determining sizes. For the beginner, fixed magnification settings should therefore be used from a didactic point of view. The operative microscope is however only a part of the normal macro habitat – the operation room. Although the microscopes may be similar and therefore easy to learn to use, all operative rooms are different, which makes surgical rehearsal difficult compared with what aeroplane pilots experience – all their cockpits = macrohabitats are equal!

The solution to the problem of timing is to accept that the pace of learning, of whatever skill, is a personal one. This means that all our dexterity learning should be self-administered, self-monitored and continuous [7, 17, 39, 50].

2.2.5 Virtual Reality as Part of the Learning Process

Surgeons need to learn how to use all the modern technological facilities that exist today including information technology (IT) and virtual reality (VR). VR is defined as an artificial world resembling 'real life' (RL) [52, 53]. Most research is that which changes the way we think about an issue or a technical problem. The data explosion we all must deal with needs to be more manageable, more coherent and more meaningful to give us a superior performance [24, 30, 40]. We will filter more and more of the surgical 'chaff', allowing truly imaginative and creative research results, whether clinical or basic, to have their appropriate input [2, 47]. One of the goals of surgical media management should be to decrease the volume of data distributed and thereby increase the significance of new information presented. We must reduce the 'information fatigue syndrome' that is so common today [2].

Virtual reality gives a substantial contribution to interactive learning environments. Virtuality in this context should be used according to its meaning 'potential/possible', making it a medium for communication of surgical skills. This is in accordance with our own findings with the Dextroscope training [5, 24, 30]. It combines the realism (as in a video recording) with the manipulative reality as in simulation programs.

Virtual reality is a desired technology for those applications in which reality does not exist (yet), cannot be accessed, or is too dangerous or expensive to disclose [24, 30]. VR gives us the possibility to rehearse complications before they occur and without injuring patients [25, 32, 50]. VR has also been described as a tool that allows a 'broadening [of] our channels of sensation and communication' [52]. The power of VR as a learning tool comes from the possibilities to explore cause-and-effect relationships in a safe environment, and to understand and prepare for various difficult scenarios [16]. Learning in a VR world is interactive and not merely receptive. Learning in the VR space also lacks the stressed atmosphere of the operating theatre and is therefore an optimal educational environment for the novice surgeon [3, 17, 34].

Within high-risk organisations such as the military and the aircraft, nuclear and chemical industries, the opportunities to learn are not only through normal learning means but also always with simulation included [27]. The VR environment can also allow the trainee to practice a skill several times as a refresher course. Surgeons and pilots that continuously make a certain type of mistake generally make more of other types of mistakes too.

Findings have also proved skill acquisition by VR training in that subjects with lower spatial abilities demonstrated a significant positive transfer from a simulator-based training task to a similar real world robotic operations task [50].

As already stated, the trainee must develop a plan for his/her dexterity training. A key point in surgical training today is to set personal dexterity goals, develop personal methods/protocols for reaching these goals, secure validation of how the goals are reached and learn to perform these dexterity tasks in settings that simulate the operating theatre environment with all its distraction [4, 6, 35, 42]. VR can be employed to test the essential abilities of a surgical candidate, and to test and train his/her surgical skills in order to orchestrate his/her actions in a new surgical habitat. Subjects with higher spatial skills did not response as positively from training in a simulated environment.

Virtual reality systems introduce the alluring possibility of a completely objective measurement and assessment of the trainee's ability [44, 46, 48, 51]. VR also makes it possible to track training developments, being an electronic and digital environment. This enhances the opportunities of the trainee to receive feedback from 'a supervisor' that is always available and thus gives the possibility of tracking development in training and rehearsal. In Lufthansa they showed that 75% of all failures were caused by non-human errors, only 13% by technical mistakes and 12% were due to environmental causes. The personality of a neurosurgeon influences the operative outcome significantly – but is never tested today [38].

To me the purpose of our new technology is to broaden our channels of sensation and communication, allowing us to experience reality more fully and making us more creative in the face of life's challenges. I think it is plausible to suggest that progress toward this goal may depend more on technology expanded sensual experience than on computer-supported reason. (John Waterworth)

Surgery is today a 'high-risk' task. In high-risk surgery, surgeons are facing special demands in terms of both physical stress and emotional stress. VR introduces the possibilities for learning surgical performance in a setting where failures will not lead to human disasters. Another important feature of surgery is preparedness and control of stress, e.g. mental status of the surgeon. If we make surgical mistakes, such as occluding a vessel by suturing, rupture of an aneurysm during dissection or not being able to localise our target, this will not injure our virtual models as it would a real patient. We know from athletes that one of the most important issues for them to be ready for an Olympic gold medal is to have dealt with all possible mistakes and thus know that they can manage the situation. We know that 70% of surgeons tend to feel that they can cope with a surgical procedure even when tired, whereas only 26% of aeroplane pilots think the same [45]. By making the mistakes, experience grows and perfection is developed. For surgeons this is only morally allowed in a VR scenario [24, 37].

In every surgical procedure there are a few key steps that the trainee is more likely to perform incorrectly leading to complications. VR is therefore considered a new medium for communication of surgical skills. The value of a surgical simulator and of continuous training is analogous to the proven value of a flight simulator [27]. A surgical simulator should train surgeons for principal pitfalls. However, the transfer of learning from such contexts to that of the operating theatre may not be as easy as is assumed by many medical training programmes [19, 36, 39, 41, 43, 44, 49, 50].

The fast propagation of www-based tele-learning can benefit from the VR prospects in the coming years, as VR programs can now be accessed by the most common web browsers such as Explorer, Safari, Mozilla, etc. [33, 43, 47].

Virtual reality will replace the customary physical congregation for lectures, workshops, scientific communications and personal interactions. Features of virtual conferences will quite easily include lectures, workshops and poster presentations [2].

If the goal of the educational experience is to foster excitement about a subject or to encourage learning though exploration, VR may be worth the expense.

2.2.6 Conclusion

In surgery one trains at random, based on a time-based system; some trainees will devote a significant amount of time to their education while others will rely on relatively passive knowledge receiving. There is often no plan for developing surgical skills and absolutely no information in the training on the role different working spaces gives us. We know today that 70% of all mistakes and unintended failures are linked to human errors. Therefore a close evaluation of the surgical skills/task performances must be included in future education. A considerable amount of evidence proves that training by computerised models facilitates the learning process [5, 16, 24, 29, 30, 33–35, 40, 53]. We cannot depend on the techniques and information learned during a short training period being adequate for an entire career: learning surgical skills is a lifelong task.

If we do not learn from our mistakes we are doomed to continue with these.

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