

Towards a Global Understanding and Standardisation of Education and Training in Microsurgery

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With an increasing emphasis on microsurgery skill acquisition through simulated training, the need has been identified for standardised training programmes in microsurgery. We have reviewed microsurgery training courses available across the six continents of the World. Data was collected of relevant published output from PubMed, MEDLINE (Ovid), and EMBASE (Ovid) searches, and from information available on the Internet of up to six established microsurgery course from each of the six continents of the World. Fellowships and courses that concentrate on flap harvesting rather than microsurgical techniques were excluded. We identified 27 centres offering 39 courses. Total course length ranged from 20 hours to 1,950 hours. Student-to-teacher ratios ranged from 2:1 to 8:1. Only two-thirds of courses offered *in-vivo* animal models. Instructions in microvascular end-to-end and end-to-side anastomoses were common, but peripheral nerve repair or free groin flap transfer were not consistently offered. Methods of assessment ranged from no formal assessment, where an instructor monitored and gave instant feedback, through immediate assessment of patency and critique on quality of repair, to delayed re-assessment of patency after a 12 to 24 hours period. Globally, training in microsurgery is heterogeneous, with variations primarily due to resource and regulation of animal experimentation. Despite some merit to diversity in curricula, there should be a global minimum standard for microsurgery training.

Keywords Curriculum / Education / Microsurgery / Teaching

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INTRODUCTION

Microsurgery is a fundamental technique in the armamentarium of the reconstructive surgeon, key to vascular anastomoses, neurovascular anastomoses, and lymphatic anastomoses. It is an essential

component of an increasing number of surgical specialties since its birthplace in Plastic Surgery. To become proficient in microsurgery, attendance at instructional microsurgery courses has become a popular, augmenting the apprenticeship model of learning in the operating theatre. Training facilities in micro-

surgery are found throughout the World [1-9], and the aim of any basic microsurgery course is to introduce the fundamental techniques required for microsurgical dissection and anastomosis. Completion of a course does improve microsurgical skills within a short time period in most trainees [10]. However in one study of trainees who attended a 1 week microsurgery training course 60% had improved, 10% had remained the same, and 30% had got worse when assessed using global rating scales of microvascular anastomoses [11]. A further study found that those completing a microsurgical course or fellowships were not necessarily able to complete a vascular anastomosis at a satisfactory rate of patency [12].

With the increasing use of microsurgical techniques and with the variety of training courses available, there is a need for standardisation. We conducted a review to compare the present courses in microsurgery available around the world as a foundation to the development of an International quality standard.

METHODS

Information was obtained from: 1) a systematic literature search within the database PubMed, MEDLINE (Ovid) and EMBASE (Ovid) published in the last 20 years (1992 to 2012); 2) a comprehensive search within the Internet; 3) a survey on teaching microsurgery distributed amongst microsurgery trainers.

The names of up to six established microsurgery training centres in microvascular anastomoses from each of the six continents (Africa, Asia, Australasia, Europe, North America, and South America) were identified. Fellowships and courses that emphasise only flap harvesting were excluded. A questionnaire was distributed to microsurgery trainers based around the world. The questionnaire supplemented the information found on the Internet and the systematic literature search. It asked how many days courses ran, how many hours per day of course, what material was used in training, what was the training progression, was there any course evaluation, was there a final examination, and what was the cost of attending a course.

The results were organised into a database containing two parts. The first part established the *characteristics* of the training course, such as the duration, the student-to-trainer ratios, and the cost of the course offered. The second part determined the specific content of the training course, such as which technical aspects of microsurgery were taught, and the method of assessment.

RESULTS

Those centres reviewed offered a basic course in microsurgery, with some offering an additional advanced course for the more

experienced surgeon. We received questionnaire responses from Europe and America. Overall, we identified 27 centres in six continents offering 39 courses (Africa: two centres, three courses; Asia: six centres, nine courses; Australasia: one centre, one course; Europe: six centres, eleven courses; North America: six centres, nine courses; South America: four centres, five courses; and one international course) (Tables 1, 2).

Characteristics of the courses

The duration of course ranged from 20 hours to 1950 hours, and divided into categories of less than 35 hours, 35 to 45 hours (5 day period), and more than 45 hours (Fig. 1). The median duration of a course was 40 hours.

The number of trainees differed for each course, and some only permitted 3 trainees, whilst another programme accommodated 25 trainees. The trainee-to-trainer ratio ranged from 2:1 to 8:1 (average between 3:1 and 4:1).

The cost of attending a basic microsurgery course, excluding travel, accommodation, and food, ranged from 300 USD to 2,400 USD (mean 1,236 USD), and averaged approximately 260 USD per day. In contrast, the cost of attending an advanced microsurgery course ranged from 700 USD to 13,200 USD (mean 2,328 USD), and averaged approximately 296 USD per day.

Contents of the courses

The 39 courses found were divided into two main groups: A and B. Type A are basic courses that emphasise the fundamental principles of the practice of microsurgical techniques, including the use of the operating room microscope, micro-instruments, micro-sutures, and are identical for all trainees regardless of their surgical specialty. Type B are *advanced* courses that build upon previous experience, allow trainee to revise fundamental microsurgical techniques, and provide an opportunity to learn additional microsurgical techniques applicable to a trainee's specialty. Nearly all the centres reviewed offered a type A course, and 12 of the 27 centres also offered a type B course.

In type A courses (Table 3) (Fig. 2), 86% offered practice on non-living models such as the latex glove, practice card and silicone tubing as a starting point in training. 52% offered practice of anastomosis in larger arteries (> 1 mm diameter), such as the rat aorta or carotid artery, and 96% offered practice on anastomosis in smaller arteries (\leq 1 mm diameter), such as the femoral artery. Venous anastomosis training was available in 91% of type A courses, and the vessels offered included the internal jugular vein, infrahepatic vena cava, and femoral vein (0.9 to 1.3 mm diameter). *Ex-vivo* animal models often used in 39% of type A courses included chicken legs, cryo-preserved rat aortas,

Table 1. Comparison of characteristics of basic microsurgery courses

Institution	Duration	Maximum trainees	Trainee: trainer ratio	Cost USD	Cost USD/day
Africa					
Zagazig University Hand Microsurgery Center, Cairo, Egypt	40 hr (5 day)	Not stated	Not stated	1,000	200
Stellenbosch University, Tygerberg Hospital, South Africa	24-32 hr (3 or 4 day)	Not stated	Not stated	300 or 350	100 or 88
Asia					
Chinese University of Hong Kong, Hong Kong	20 hr (5 half day)	Not stated	Not stated	520	104
Ganga Microsurgery Training Institute, Coimbatore, India	40 hr (5 day)	4	2:1	750	150
King Faisal Specialist Hospital and Research Centre, Saudi Arabia	40 hr (5 day)	7	Not stated	Not stated	Not stated
National University Hospital, Singapore	44 hr (5 day)	4	2-4:1	1,000	200
Singapore General Hospital, Singapore	40 hr (5 day)	20	6:1	1,200	240
Gulhane Military Medical Academy, Turkey	45 hr (5 day)	5	3-5:1	Not stated	Not stated
Australasia					
Microsearch Laboratory, University of Sydney, Sydney	40 hr (5 day)	12	Not stated	Not stated	Not stated
Europe					
Erasmus MC, Universitair Medisch Centrum Rotterdam, Netherlands	40 hr (5 day)	6	2:1	2,100	420
Pius Brnzeu Center, Victor Babes University, Timisoara, Romania	32 hr (3.5 day)	14-17	3:1	910	260
Ecole de Chirurgie de L'Assistance Publique-Hospitaux de Paris, France	20 hr (3 day)	11	11:2	320	107
Maz Microsurgical Training Center, Linz, Austria	24 hr (3 day)	18	4:1	800	267
Centro Traumatologico Ortopedico, Torino, Italy	5 day	20	4:1	800-1,600	160-320
Norwich Park Institute for Medical Research, UK	35-40 hr (5 day)	16	8:1	2,400	480
North America					
University of Louisville, Kentucky, USA	35-40 hr (5 day)	4	4:1	2,000	400
Mayo Clinic Campus, Minnesota, USA	40 hr (5 day)	4	4:1	1,875	375
Columbia University, New York, USA	35-40 hr (5 day)	3	3:1	1,900	380
Indiana University Medical Center, Indiana, USA	40 hr (5 day)	Not stated	Not stated	1,500	300
MOET Institute, c/o The Buncke Clinic, California, USA	40 hr (5 day)	Not stated	Not stated	950-1,500	190-300
McMaster University, Ontario, Canada	40 hr (5 days)	Not stated	Not stated	2,000	400
South America					
Instituto de Ortopedia e Traumatologia, Sao Paulo, Brazil	40 hr (5 day)	5	Not stated	1,000	200
Instituto Nacional do Cancer, Rio de Janeiro, Brazil	100 hr (25 day)	Not stated	Not stated	Not stated	Not stated
Hospital Universitario Walter Cantidio, Fortaleza, Brazil	60 hr	Not stated	Not stated	Not stated	Not stated

and porcine coronary arteries. 90% used *in vivo* animal models, in particular the anaesthetised rat. All type A courses provided instructions in microvascular end-to-end anastomoses, and 78% provided instructions in end-to-side anastomoses. Instruction in interposition vein grafting, peripheral nerve repair, or flap transfer were offered by 82%, 48%, and 22% of type A courses, respectively (Table 3, Fig. 3).

In type B courses, course duration ranged from 12 hours to 1,950 hours. One centre offered a flexible duration tailored to trainee requirements. All courses offered revision of basic microsurgery techniques. Additional instruction included complete replantation of rabbit ears, groin free flap transfer using the femoral vessels or superficial inferior epigastric vessels as recipient vessels. Some also offered specialty-orientated instruction, such as vasovasostomy and vasoepididymostomy for urology

trainees, fallopian tube anastomosis for obstetric and gynaecology trainees, and organ transplantation models (renal) for transplantation surgeons.

The different assessment methods were found, and we categorised them into: 1) No formal assessment—where an instructor monitored progress and gave feedback and subjective skill evaluation throughout the course; 2) Immediate assessment of vessel patency—after a 30 minutes to 2 hours period; 3) Delayed reassessment of vessel patency—after a 12 to 24 hours period.

Seventy-five percent of type A courses had no formal assessment. Five centres (21%) evaluated the patency of microvascular anastomosis at 30 minutes to 2 hours post-intervention, and if unsuccessful, trainees had to repeat the assessment. Proficiency tests involved completion of both femoral arterial and venous anastomoses within a specific time frame. Only one centre

Table 2. Comparison of characteristics of advanced microsurgery courses

Institution	Duration	Maximum trainees	Trainee: trainer ratio	Cost USD	Cost USD/day
European School of Reconstructive Microsurgery, International Faculty	1,950 hr (2 yr)	9-25	Not stated	7,900-13,200	Not stated
Zagazig University Hand Microsurgery Center, Cairo, Egypt	40 hr (5 day)	Not stated	Not stated	1,000	200
Chinese University of Hong Kong, Hong Kong	22 hr (5 half day)	Not stated	Not stated	770	154
King Faisal Specialist Hospital and Research Centre, Saudi Arabia	14-21 hr (2-3 day)	7	Not stated	Not stated	Not stated
National University Hospital, Singapore	26 hr (3 day)	3-4	2-4:1	1,000	333
Pius Branzu Center, Victor Babes University, Romania	3 day (or more)	Not stated	Not stated	Not stated	120
Ecole de Chirurgie de l'Assistance Publique-Hospitiaux de Paris, France	120 hr (8 mo)	Not stated	Not stated	800	Not stated
Maz Microsurgical Training Center, Linz, Austria	16 hr (2 day)	10	4:1	800	267
Azienda Ospedaliera Di Rilievo Nazionale, Napoli, Italy	124 hr (15 day)	15	Not stated	3,200	213
Norwick Park Institute for Medical Research, UK	40 hr (5 day)	Not stated	Not stated	3,200	640
Columbia University, New York, USA	40 hr (5 day)	3	3:1	1,700	340
Indiana University Medical Center, Indiana, USA	12 hr (2 day)	Not stated	Not stated	900	450
MOET Institute, c/o The Buncke Clinic, California, USA	40 hr (5 day)	Not stated	Not stated	950-1,500	190-300
Argentina Association of Hand Surgery, Argentina	20 hr (3 day)	Not stated	Not stated	700	233
Instituto de Ortopedia e Traumatologia, Sao Paulo, Brazil	40 hr (5 day)	5	Not stated	1,500	300

Fig. 1. Duration of courses offered by centres

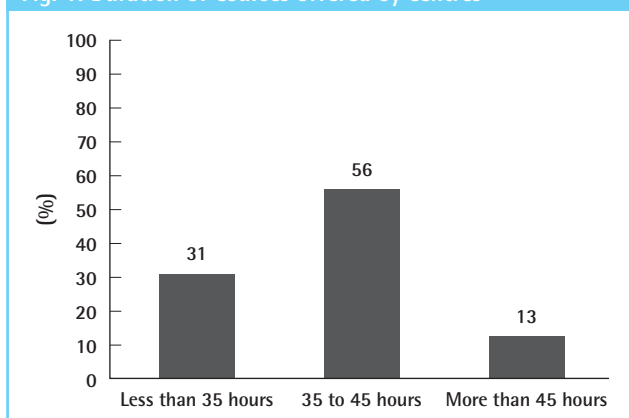
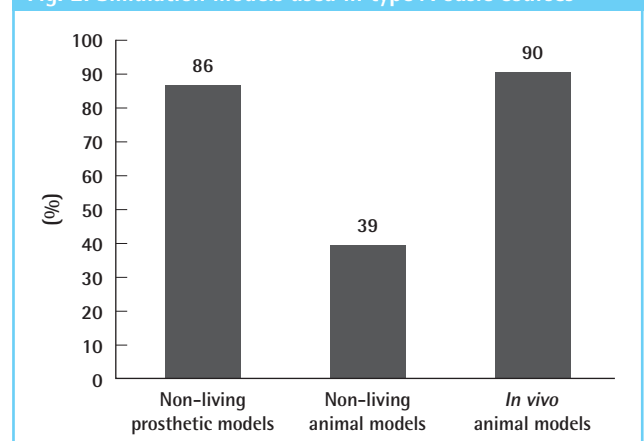


Fig. 2. Simulation models used in type A basic courses



also assessed trainees with a previously published global rating scale (GRS), with a final grade calculated based on microsurgical technique and time taken. One centre (4%) inspected the previous day's vascular repair for vessel patency, which allowed an opportunity to discuss reasons for thrombosis and to correct any technical errors.

DISCUSSION

Microsurgery training across the World is heterogeneous. Courses vary in duration, but most of the centres identified offered a 35 to 45 hours (5 days) training schedule. Some offered an *advanced* course in addition to a *basic* course. There was considerable variation in the trainee-to-trainer ratio, which may prove

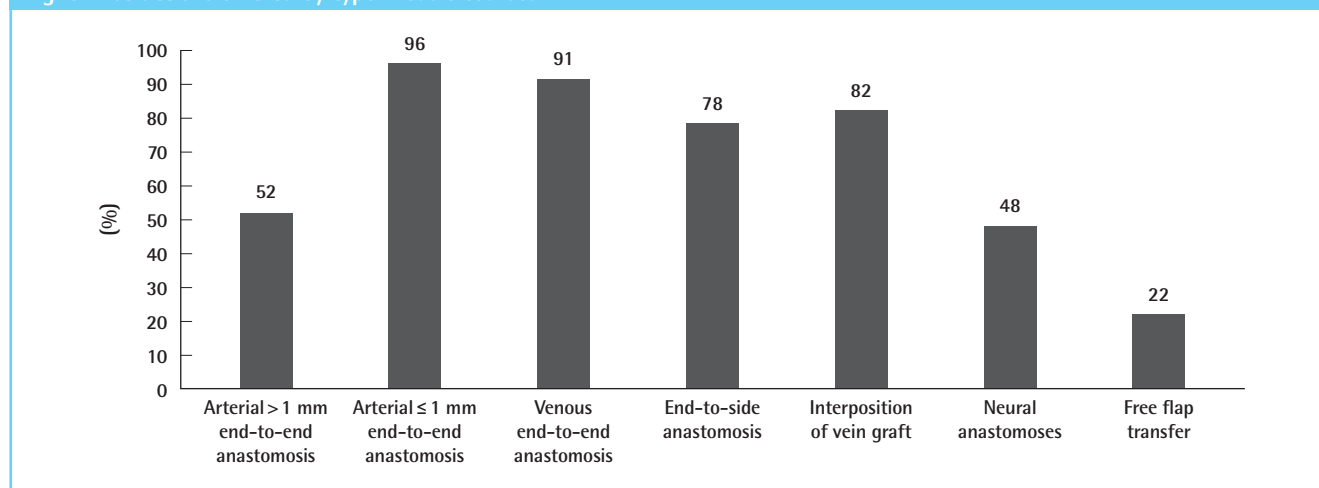
to have an effect on the trainee's learning through immediate feedback.

Ex-vivo prosthetic models such as the latex glove, silicone sheets and tubing, although not offered by all, were a common starting point in training. This was generally followed by a variety of non-living animal models, such as the porcine coronary artery, and chicken leg artery. Majority of courses offered *in vivo* animal models. The advantages of non-living and prosthetic models are: portability, minimal maintenance over a favourable shelf life, and with no biological hazards or regulations for their use—but they may not be as realistic as living models [13]. Silicone tubes simulating small blood vessels can be useful to practice handling microvascular instruments and for novices to familiarise themselves with microsurgical techniques, and perhaps for periodic

Table 3. Comparison of simulation models and instructions offered by basic microsurgical courses

Institution	Non-living prosthetic model	Non-living animal model	In vivo animal model	Larger arterial end-to-end	Smaller arterial end-to-end	Venous end-to-end	End-to-side	Interposition of vein graft	Neural anastomosis	Flap transfer
Zagazig University Hand Microsurgery Center, Cairo, Egypt	Yes	-	Yes	No	Yes	Yes	Yes	Yes	No	No
Stellenbosch University, Tygerberg Hospital, South Africa	Yes	-	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Chinese University of Hong Kong, Hong Kong	Yes	-	Yes	Yes	Yes	No	No	No	No	Yes
Ganga Microsurgery Training Institute, Coimbatore, India	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No
King Faisal Specialist Hospital and Research Centre, Saudi Arabia	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
National University Hospital, Singapore	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Singapore General Hospital, Singapore	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gulhane Military Medical Academy, Turkey	No	-	-	Yes	Yes	No	Yes	Yes	No	No
Microsearch Laboratory, University of Sydney, Sydney	-	-	-	-	-	-	-	-	-	-
Erasmus MC, Universitair Medisch Centrum Rotterdam, Netherlands	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Pius Brnzeu Center, Victor Babes University, Timisoara, Romania	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Ecole de Chirurgie de L'Assistance Publique-Hospitaux de Paris, France	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No
Maz Microsurgical Training Center, Linz, Austria	No	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No
Centro Traumatologico Ortopedico, Torino, Italy	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No
Norwich Park Institute for Medical Research, UK	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
University of Louisville, Kentucky, USA	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No
Mayo Clinic Campus, Minnesota, USA	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Columbia University, New York, USA	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Indiana University Medical Center, Indiana, USA	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
MOET Institute, c/o The Buncke Clinic, California, USA	-	-	-	-	Yes	Yes	Yes	Yes	Yes	No
McMaster University, Ontario, Canada	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes
Instituto de Ortopedia e Traumatologia, Sao Paulo, Brazil	Yes	Yes	-	-	Yes	Yes	No	No	No	No
Instituto Nacional do Cancer, Rio de Janeiro, Brazil	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Hospital Universitario Walter Cantidio, Fortaleza, Brazil	Yes	Yes	No	No	Yes	Yes	No	No	No	No

Fig. 3. Instructions offered by type A basic courses



retraining of more established surgeons [14]. Interestingly, novices trained on low fidelity prosthetic models performed as well as those trained on high fidelity live rats [15]. Currently the most commonly used animal in microsurgical courses is the rat [16]. Trainees prefer cryo-preserved rat arteries over silicone tubes [17], and the former can be used for initial training exercises prior to progression *in vivo* models. The benefit of using *in vivo* models is that the normal clotting process is replicated. However, regulation of animal experimentation, increased scrutiny of the ethical use of laboratory animals, and the cost of maintaining an *in vivo* laboratory limit their availability.

As a result, microsurgery educators are being confronted by a compelling ethical argument to strongly apply Russell and Burch 3 R's of "Replacement, Refinement and Reduction" to the use of living animal models in microsurgery training courses [18]. Accordingly, and increasingly, it will be necessary to demonstrate the adherence to these ethical principles of replacing the animal models with synthetic or non-living models where possible, refining the conditions and the educational interventions for which living animals models would be used and reducing such animals to a minimum before microsurgery training courses would be authorised to include living animal models in its taught exercises as is the case in biomedical research [19]. For example, the UK's Animals (Scientific Procedures) Act 1986 aim to balance the legitimate needs of medical research and education with the welfare of the animals. This legislation applies to microsurgery education in the UK and restricts both the number of centres using living animals for microsurgery training and the number of animals used by each trainees by necessitating a certificate of designation (for the institution), a project licence (for the training programme) and a personal licence (for the student) before conducting microsurgery on living animals is authorised. This level of regulation would soon be the norm in Europe and worldwide. Currently, centres that provide living animal models as part of their training programmes are shown in Table 3.

Instruction in microvascular end-to-end and end-to-side anastomoses are common to most *basic* programmes, with half the courses offering practice on larger arteries (> 1 mm diameter) prior to practice on smaller arteries (\leq 1 mm diameter). However, instruction in interposition vein grafting, peripheral nerve repair, or flap transfer were not consistently offered. *In vivo* vascular models provide an opportunity for reviewing the functional results of anastomoses. Nerve models demand a different dissection and tissue handling. Thus with the variation in course costs, trainees should consider these factors.

The vast majority of centres did not make formal assessments of skill, skill acquisition or skill maintenance. Trainees receive

guidance and feedback throughout the course and are given a certificate of completion, rather than one of competency. Criteria-based observation with checklists and GRS are more objective processes. Kalu et al. [20], adapted a checklist for end-to-end arterial anastomosis, but checklists demonstrate low levels of construct validity [21]. GRS consist of a number of important components of a task, such as suture handling, and are graded on a Likert scale with statements as anchor points. When used by trained assessors, GRS demonstrate good reliability and validity [22]. Grober et al. [23] developed a GRS for microsurgery. More recently, the University of Western Ontario Microsurgery Skills Acquisition/Assessment (UWOMSA) instrument was developed to assess microsurgical skill, in particular, knot tying and anastomosis [24]. Hand motion analysis (HMA) is another method for objective assessment of microsurgical skills [23], and it has been shown to correlate well with GRS and trainees with better dexterity scores produced vascular anastomoses that leaked less [25]. Vessel patency, an analysis of the final product in five centres (21%), may be an important method of assessment because it is crucial for flap survival in successful microvascular free tissue transfer [26]. Szalay et al. [27] showed that novice surgeons had to performed between 40 and 48 vessel anastomoses to achieve 100% patency on live rats two weeks after the procedure. They also concluded that end product assessment on bench top models correlated well with GRS, time taken, and year of training. However, more research is required to determine whether which is more effective in assessing competency. Although assessments can be labour-intensive, it will become increasingly important to be able to gauge trainees' progress, and criteria-based tools can aid teaching and end-of-course evaluation.

There must be merits in the diversity of available courses whilst this area is in a process of development, but there is an increasing argument for standardisation of courses, and for more objective assessment measures of skill, skill acquisition and skill maintenance. Patients should have a reasonable expectation of consistent standards of surgical treatment. With the publications of medical errors and adverse events [28], training and certifying bodies are urged to develop new ways to show evidence of a surgeon's competence to ensure quality. Attendance of microsurgery courses and even operative experiences cannot lead us to presume that trainees have reached a certain level of competency [29,30]. A standardised training with formal assessments in competency must coexist [31]. In UK, the Joint Committee on Surgical Training (JCST) acts as an advisory body to develop quality assurance in surgical training, and through Intercollegiate Surgical Curriculum Programme (ISCP), it has worked towards a nationally standardised curriculum, which

is underpinned by clearly defined standards and competency-based assessment for each stage of surgical training [32]. Similarly in colon and rectal surgery training in Europe, there are no minimum standards for training, no training unit recognition process, and no minimum time requirement for training in coloproctology. Plans are underway to define minimum standards of training to guarantee consistent standards of care [33]. Colorectal trainees would need to satisfy activity requirements for numbers of procedures, and to undergo procedure based assessments, along with examinations. Microsurgery training may benefit from looking at the system set up for endoscopy training. Endoscopy is housed principally within medical and surgical gastroenterology, but radiologists, general practitioners and nurses also perform endoscopic procedures. The Joint Advisory Group (JAG) on gastrointestinal endoscopy (UK) was established in 1994 to provide quality assurance of endoscopy units, training and services [34]. All trainees in endoscopy must attend a JAG certified Basic Skills in Upper or Lower GI endoscopy course, which include formal instruction on indications and contraindications of endoscopic procedures, techniques of conscious sedation, maintenance, cleaning and disinfection of endoscopes and equipment, and recognition and management of complications. Training should only take place in units approved by the JAG, thus allowing for standardised training and assessment based on identical and agreed competences [35]. As we approach the era of surgical revalidation [36], standardisation in education and training would facilitate development and maintenance of microsurgical skills.

REFERENCES

1. Abreo N, Sivathanan N. Microsurgery training course, Columbia University, New York [Internet]. London: BMJ Careers; 2009 [cited 2012 Dec 18]. Available from: <http://careers.bmj.com/careers/advice/view-article.html?id=20000467>.
2. Goossens DP, Gruel SM, Rao VK. A survey of microsurgery training in the United States. *Microsurgery* 1990;11:2-4.
3. Izci Y, Timurkaynak E. A short history of the microsurgery training and research laboratory at Gulhane Military Medical Academy. *Turk Neurosurg* 2010;20:269-73.
4. Klein I, Steger U, Timmermann W, et al. Microsurgical training course for clinicians and scientists at a German University hospital: a 10-year experience. *Microsurgery* 2003; 23:461-5.
5. Mofikoya BO, Ugboro OA, Bankole OB. Challenges in the organisation of a microsurgery laboratory in a low resource country. *Niger Postgrad Med J* 2010;17:60-3.
6. Tadiparthi S. Microsurgery course [Internet]. London: BMJ Careers; 2007 [cited 2012 Dec 18]. Available from: <http://careers.bmj.com/careers/advice/view-articles.html-id=2421>.
7. University of Sydney. Microsearch establishes new microsurgery course [Internet]. Sydney: Microsearch Foundation of Australia; 2010 [cited 2012 Dec 18]. Available from: http://sydney.edu.au/medicine/foundation/microsearch/publications/Newsletters/MicroNews_June10.pdf.
8. Wilson E. Inaugural European Louisville Microsurgery Course—Frankfurt [Internet]. London: BMJ Careers; 2008 [cited 2012 Dec 18]. Available from <http://careers.bmj.com/careers/advice/view-articles.html-id=3176>.
9. Yoong P. Microsurgery in India [Internet]. London: BMJ Careers; 2007 [cited 2012 Dec 18]. Available from <http://careers.bmj.com/careers/advice/view-articles.html-id=2566>.
10. Starks JL, Payk I, Hodges NJ. Developing a standardized test for the assessment of suturing skill in novice microsurgeons. *Microsurgery* 1998;18:19-22.
11. Atkins JL, Kalu PU, Lannon DA, et al. Training in microsurgical skills: does course-based learning deliver? *Microsurgery* 2005;25:481-5.
12. Studinger RM, Bradford MM, Jackson IT. Microsurgical training: Is it adequate for the operating room? *Eur J Plast Surg* 2005;28:91-3.
13. Lannon DA, Atkins JA, Butler PE. Non-vital, prosthetic, and virtual reality models of microsurgical training. *Microsurgery* 2001;21:389-93.
14. Peled IJ, Kaplan HY, Wexler MR. Microsilicone anastomoses. *Ann Plast Surg* 1983;10:331-2.
15. Grober ED, Hamstra SJ, Wanzel KR, et al. The educational impact of bench model fidelity on the acquisition of technical skill: the use of clinically relevant outcome measures. *Ann Surg* 2004;240:374-81.
16. Berezniak R. Creating, developing and mastering a superior microsurgical technique. Reading, PA: Sharpoint; 1991.
17. Russell WM, Burch RL. The principles of humane experimental technique. London: Methuen; 1959.
18. Baumans V. Use of animals in experimental research: an ethical dilemma? *Gene Ther* 2004;11 Suppl 1:S64-6.
19. Lausada NR, Escudero E, Lamonega R, et al. Use of cryopreserved rat arteries for microsurgical training. *Microsurgery* 2005;25:500-1.
20. Kalu PU, Atkins J, Baker D, et al. How do we assess microsurgical skill? *Microsurgery* 2005;25:25-9.
21. Taylor JB, Binbaum G, Tapino P, et al. Microsurgical lab testing is a reliable method for assessing ophthalmology residents' surgical skills. *Br J Ophthalmol* 2007;91:1691-4.
22. Reznick R, Regehr G, MacRae H, et al. Testing technical

- skill via an innovative “bench station” examination. *Am J Surg* 1997;173:226-30.
23. Grober ED, Hamstra SJ, Wanzel KR, et al. Validation of novel and objective measures of microsurgical skill: Hand-motion analysis and stereoscopic visual acuity. *Microsurgery* 2003;23:317-22.
 24. Temple CL, Ross DC. A new, validated instrument to evaluate competency in microsurgery: the University of Western Ontario Microsurgical Skills Acquisition/Assessment instrument. *Plast Reconstr Surg* 2011;127:215-22.
 25. Datta V, Mandalia M, Mackay S, et al. Relationship between skill and outcome in the laboratory-based model. *Surgery* 2002;131:318-23.
 26. Gardiner MD, Nanchahal J. Strategies to ensure success of microvascular free tissue transfer. *J Plast Reconstr Aesthet Surg* 2010;63:e665-73.
 27. Szalay D, MacRae H, Regehr G, et al. Using operative outcome to assess technical skill. *Am J Surg* 2000;180:234-7.
 28. Keogh B, Spiegelhalter D, Bailey A, et al. The legacy of Bristol: public disclosure of individual surgeons' results. *BMJ* 2004;329:450-4.
 29. Lowry J, Cripps J. Results of the online EWTD trainee survey. *Ann R Coll Surg Engl (Suppl)* 2005;87:86-7.
 30. Beard JD. Assessment of surgical skills of trainees in the UK. *Ann R Coll Surg Engl* 2008;90:282-5.
 31. Reznick RK, MacRae H. Teaching surgical skills: changes in the wind. *N Engl J Med* 2006;355:2664-9.
 32. Joint Committee on Surgical Training [Internet]. London: JCST; 2012 [cited 2013 Mar 03]. Available from: <http://www.jcst.org>.
 33. American Society of Colon & Rectal Surgeons. Pan European Standardisation of Training in Colon and Rectal Surgery [Internet]. Arlington Heights, IL: ASCRS; c2013 [cited 2013 Mar 03]. Available from: http://www.fascrs.org/aboutus/international_iccp/international_training_standards/.
 34. Joint Advisory Group on GI Endoscopy [Internet]. London: The JAG; 2013 [cited 2013 Mar 03]. Available from <http://www.thejag.org.uk/>.
 35. Association of Upper Gastrointestinal Surgeons of GB&I (AUGIS) and Association of Coloproctology of GB&I (ACPGBI). Recommendations for endoscopic training for gastrointestinal surgeons [Internet]. London: Association of Upper Gastrointestinal Surgeons of Great Britain and Ireland;2010 [cited 2013 Mar 03]. Available from http://http://www.augis.org/pdf/reports/Combined_views_on_endoscopic_training_for_surgeons_FINAL.pdf.
 36. General Medical Council. Revalidation [Internet]. London: General Medical Council; 2013 [cited 2013 Mar 03]. Available from <http://www.gmc-uk.org/doctors/revalidation.asp>.