

REVIEW

Training for Infrainguinal Bypass Surgery

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Background. Despite satisfactory results for surgery performed by trainees, vascular surgeons need to improve training methods to ensure that aspiring surgeons are adequately trained with less clinical exposure during fewer dedicated years of training.

Objectives. To review the wide range of workshop, laboratory and seminar-room based methods available to train for the diverse range of skills required for distal arterial revascularisation. Training methods include anastomotic suturing skills with bench-top training apparatus, working with realistic plastic models and prosthetic conduits, cadaveric dissections and virtual-reality simulations. Many of these also provide excellent opportunities for objective assessment of technical skills and trainees' progress.

Design and Methods. A review of the literature on surgical education, surgical skills training and assessment. An evaluation of some of the apparatus, facilities, training curricula and courses, currently available to European trainees, is carried out.

Conclusions. Many methods are now available to allow focused training for particular skills in non-clinical settings. Objective tools are also available that allow assessment of trainees at many levels or practicing surgeons. These technical skills assessment methods are important for trainees and surgeons who, in the future, will increasingly need to demonstrate competence in vascular surgery.

Key Words: Bypass surgery; Surgical training workshops.

Introduction—Current Problems We All Face

Despite current satisfactory results for surgery performed by trainees,^{1,2} vascular surgeons need to improve training methods to ensure that aspiring surgeons are adequately trained in the future with less clinical exposure during fewer dedicated years of training. The Department of Health (UK) in line with the European Working Time Directives^{3,4} has currently imposed an absolute maximum of 58 h per week with further reductions to 48 h by 2009. Furthermore, the introduction in Great Britain of the junior doctors' 'New Deal' has meant a reduced number of years in specialist training.⁵ These changes in employment practice have meant that the average Higher Surgical Trainee will have their total work-hours during training reduced from 80,000 to 25,000.⁶ This new training scheme⁷ aims to produce competent consultant specialist surgeons at a younger age (32–33).⁸ The

graduates of this streamlined training programme will have different levels of experience to their Senior Registrar counterparts of 10–15 years ago.^{9,10} No longer does there exist the luxury to complete an apprenticeship style of training in all aspects of 'general' surgery.¹¹ Perhaps the traditional surgical apprenticeship was always an inappropriate model for training—whereas carpenters learn on wood and turners on scrap metal, which is then never used or displayed, operative training is performed on patients.¹²

Recently published audits of surgical and vascular trainees' operative experience and their level of supervision have highlighted the existing deficiencies.^{10,13} In the past, senior trainees in UK were considered to be experienced and less than 30% of their operations were fully supervised.¹

In Britain femoro-popliteal bypass and femoro-distal bypass are two of the Vascular Surgical Society of Great Britain and Ireland (VSSGBI) 'indicator' operations for training (abdominal aortic aneurysm repair and carotid endarterectomy being the other

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two)¹¹ and the number of supervised operations vary considerably (Fig. 1). Some trainees appear to have little supervision and others little experience while some appear to achieve adequate supervision and training.⁸

An unpublished audit of Danish Vascular Trainees has documented a relatively low exposure of their trainees to major vascular operations as the primary surgeon (during a 3-year specialist registrar program) (Table 1). The average trainee would be the primary surgeon for 24 femoro-crural bypass procedures (8 supervised) throughout their training (and assist in a further 14) (J. Sandermann—personal communication). Clearly other methods and techniques need to be developed in order to prepare them to operate as primary surgeon.

The impact of the European Working Time Directives were discussed at the most recent UEMS (Union Europeenne des Medicin Specialistes) Symposium in Istanbul, 2002.¹⁴ Presenters from many countries alluded to reductions in case numbers as a result of coming into line with the new laws. These reductions will undoubtedly have implications on the amount of operative experience and necessitate the adoption of training programs that enable trainees to acquire their skills more efficiently.¹ Clearly, there needs to be a more organized approach focused on obtaining technical skills to a suitable level without the need for as much clinical exposure.^{15–17} This will require a revised curriculum and the development of new and innovative educational methods to ensure the trainee is competent in the best practice of modern surgical and operative techniques. For the purposes of this article we will discuss the challenges and advances in surgical education as it relates to training for peripheral arterial reconstructions. A number of objective tools are also available to allow assessment of trainees and currently practicing surgeons, who may soon warrant ongoing assessment.¹⁸

Methods

An extensive search of relevant reference material was undertaken employing search engines within PubMed (National Library of Medicine, Bethesda, MD, US), OVID search engine within the MEDLINE database (NISS, US) and 'Web of Science' (Institute of Scientific Information (ISI)—Journal Citation Reports, Thomson Scientific, Philadelphia, PA, USA). Up to date and relevant articles were selected. The authors were personally involved in the organization of or participation in some of those courses reviewed (refer to acknowledgments).

Training Methods Available

Basic Surgical Training

Basic surgical training involves clinical employment within surgical units during which time assessments are undertaken by mentors and culminates in an examination, success being mandatory for progression to advanced surgical training. During surgical training a number of component training modules are undertaken.

Basic Surgical Skills Courses. These courses should familiarise trainees with basic techniques at the outset of their career in surgery. The curriculum should adhere to basic principles and sets of simplified tasks using of models and gantries to aid the trainee. Standardized models and tasks then allow assessment of an individual's competence.¹⁹ Participants receive instructional videos both prior to and during the course and then real-time video projection of the technique during each instructional module. Repeated exposure to video footage of simple procedures has also been beneficial in attaining skills more quickly.²⁰ At the same time it allows free interactive discussion and repeated demonstration of those aspects of the technique that are difficult. With a low participant to

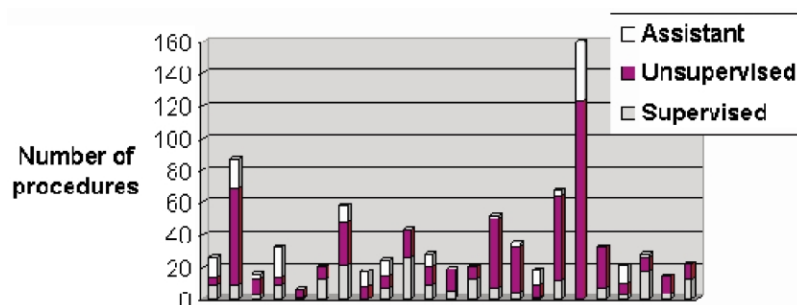


Fig. 1. A graph illustrating the variation from centre to centre for numbers of index procedure cases senior trainees perform per year with and without supervision. Wolfe JHN. Ann R Coll Surg Engl. 1998.

Table 1. An audit of 18 specialist vascular trainees in Denmark.

Year Role	1st			2nd			3rd			Totals
	Assist	3,2	1	Assist	3,2	1	Assist	3,2	1	All
Fem-AK Pop	4	8	4	3	10	3	4	8	2	46
Fem-BK Pop	4	2	3	5	6	2	3	7	2	34
Fem-Crural	4	3	2	5	5	3	5	8	3	38

Compiled from the Danish Vascular Registry. Displayed are median values for procedures performed by a group of 18 trainees completing a 3-year training program. Produced with the kind permission of Dr J. Sandermann, Denmark. Role: 3,2 = independent primary surgeon. 1 = Supervised as the primary surgeon.

instructor ratio this also facilitates valuable individual feedback²¹ and coaching through the difficult points. Tasks instructed include:

Surgical Principles. Basic instrument handling, safety with sharps and sterile techniques are essential. These can be included within instructional videos.

Surgical Knots and Suturing. Techniques can be quickly learned with a number of materials and exercises and result in greatly enhanced confidence. Once a few tasks have been taught the candidate can rehearse until competent (there can be a great variation in the aptitude of various participants).

Anastomotic Methods. Although considered to be low-fidelity simulations, rubber/plastic conduits are available with very lifelike handling and suturing qualities. This enables vascular anastomotic techniques to be taught and practiced easily and inexpensively. Arteriotomy formation and vein patch closure are currently taught on the basic surgical skills courses run by the Royal Colleges in the UK.²² More advanced techniques such as graft-to-artery anastomosis are taught during the Royal College of Surgeons (RCS) Higher Surgical Skills courses.²³

Completion of a basic surgical skills course, whilst not a barrier assessment, gives the trainee the confidence to play a more active role in their surgical team and to become more involved in discussions about the relevant and alternative techniques.

Basic Surgery Training—Course Modules. These courses are run by the Royal Colleges and specifically address Advanced Trauma Life Support (ATLS), Care of the Critically Ill Surgical Patient (CCrISP), and the computer based distance-learning 'STEP 2000' course offered as preparation for the membership examination (MRCS) (Raven Department of Education, Royal College of Surgeons of England, London, UK).²⁴

Basic Surgical Training Core Curriculum. Specific tasks and techniques that may be examined at the completion of basic surgical training are included within a universal curriculum published by the Colleges. Technical explanations are also available through computer-based training schemes, designed in conjunction with the Royal Colleges, on the World

Wide Web (Best Online, Royal College of Surgeons, Ireland, Dublin & IntuMed™ Ltd. Dublin, Ireland). A similar resource has been established by the Royal Australasian College of Surgeons (RACS) in Australia (BST Online, RACS, Australia). Instructional CD-ROM Tutors are also available in a proprietary package with suture pad and basic instruments (Limbs & Things™, Bristol, UK²⁵). These allow for revision and practice outside of working hours, away from the clinical environment without the need for face-to-face lectures.²⁶

Advanced Surgical Training

Synthetic Models. In the modern age synthetic 'body models' have become a very good alternative. Replaceable soft plastic components with dual-layered vessel walls and similar handling qualities to human tissues are commercially available (Annexart, UK). A number of models exist for complete operative techniques including: aortic aneurysm repair and Aorto-iliac or Aorto-renal bypass (Vascular International Foundation, Switzerland), sapheno-femoral junction dissection and long saphenous vein harvest (Limbs & Things™, Bristol, UK). Many more are in development (including carotid endarterectomy) and although these may be a little expensive, the range will expand in the future and become less costly. At present the cost means that courses are conducted for larger groups of trainees rather than individual institutions. Many of these have been established and are run regularly and concurrently with international and national meetings (European Vascular Workshop, Pontresina, Switzerland) (ESVS meetings) (Raven Department of Education, Royal College of Surgeons).

Virtual Reality (VR) Models and Simulations. These are designed to be of a higher fidelity (degree of realism) to the bench-top simulated tasks. These were initially introduced for the training and assessment of surgeons in revolutionary laparoscopic techniques. The surgical department at Imperial College, St Mary's Hospital, London has extended the process to other surgical techniques. They have used models simulating endoscopy,²⁷ orthopaedic²⁸ and laparoscopic^{12,29}

surgery and we are developing vascular surgery. While the fidelity of such simulations may not as yet be perfect, they do seem to replicate relevant parameters.³⁰ The use of a well validated laparoscopic simulator (Minimally Invasive Surgical Tutor or MIST-VR) has been demonstrated to improve performance of trainees that can be transferred into the operating theatre.³¹ Recently, a randomized, double blinded study conducted at Yale University School of Medicine demonstrated trainees trained on VR simulators performed better than the control group who had no VR training.³² There are suggestions that distributed blocks of practice on simulated tasks separated at many time intervals is beneficial over massed practice.³³

Endovascular Training Simulators. Endovascular skills are becoming increasingly important and are complimentary to open techniques.³⁴ Minimum numbers and standards for competence amongst radiological and surgical trainees have been published.^{8,35} Many sophisticated apparatus are available to allow acquisition of skills for endovascular access, guidewire manipulation, balloon dilatation and stent placement (Hillway Surgical, UK³⁶—designed in association with the VSSGBI) and (Foundation Vascular-International, Switzerland³⁷). Many of these employ clear plastic vessels with coloured dyes to depict angiographic type images. These have the advantage of avoiding the exposure to radiation meaning they can be utilized outside clinically sanctioned areas. The video interface will also lend itself very well to the application virtual reality simulations.

Cadaveric Dissection and Live Animal Models. These have long been a reliable method of teaching trainees of all levels and surgeons learning new or innovative procedures. Cadavers provide excellent insights into anatomical dissections and understanding of surgical planes for all forms of surgery. Cadaveric and amputated limbs (in those countries where consent can be obtained) provide excellent opportunities for training on dissection of crural or ankle vessels and anastomoses whether it be with the autologous veins or discarded prosthetic conduits. They have the greatest fidelity in terms of their anatomical faithfulness (and anatomical variability for that matter). The facilities required and costs involved are significant yet not prohibitive. Excellent courses relying on cadaveric dissection are run by the Royal College of Surgeons of England²³ and the Institute of Anatomy in Zurich, Switzerland.

Live animal models provide the greatest degree of realism with bleeding tissues with suitable tissue elasticity and size of structures in appropriately sized mammals. However, their use for training purposes

has been prohibited in the United Kingdom since The Cruelty to Animals Act (UK) of 1876 and The Protection of Animals Act (UK) 1911.³⁸ In other countries, their availability is understandably dwindling due to ethical concerns and their use is increasingly expensive. These were utilized for the training and assessment of trainees³⁹ and experienced surgeons learning new techniques but in future their smaller role will be in the trial and assessment of experimental techniques.

Live-case Training. No surgical training would be complete without the accuracy and unpredictability of real operations. There should certainly be no reduction in the numbers of cases offered to trainees but by employing a combination of all these methods in a structured training program with cumulative assessment and regular appraisal many could achieve proficiency with fewer clinical cases. There may also be a need to address the level of supervision that trainees are given. A recent audit of trainees' experience in Femoro-popliteal and Femoro-crural reconstructions demonstrated good case numbers overall but a widespread lack of consultant supervision (Fig. 1).⁸

Surgical Assessment

Validity. With any new test or form of assessment, documentation of its validity must be carried out.⁴⁰ Validity assesses whether we are in fact measuring what we are aiming to measure.⁴¹

These concepts include (1) Predictive Validity—will it predict future performance; (2) Content validity—are the skills we want to assess being measured by the tool?; (3) Concurrent validity—does this form of assessment correlate with currently accepted methods? (Gold standards); (4) Construct validity—to what extent are we measuring the trait that we want to assess?; and (5) Face validity—how realistic is the task compared to the real situation?⁹

Different methods of technical skills assessment vary in their reliability and validity and this has been well summarized previously by Watts and Feldman.⁴²

Mentor Assessment. This is the tried and trusted method of assessment of trainees under the apprenticeship system. It evaluates many of the broader attributes that surgeon mentors value in their trainees.⁴³ Whilst it has been very successful it no longer affords sufficient accountability to be completely relied upon in modern surgical training.^{41,42} Operative competence assessment forms have been advocated by the Vascular Surgical Society Joint Committee on Higher Surgical Training (in the UK and Ireland) and these have been demonstrated to show good corre-

lation with the trainees' total number of logbook cases. There is a documented variability between trainees as far as the number of procedures performed per trainee required for the achievement of operative competence.⁴⁴

Logbooks. These remain a pivotal part of all surgical training and assessment for most governing bodies, including the RCS Intercollegiate membership exam and logbook accreditation forms Part 1 of the European Board of Surgery Qualification in Vascular Surgery (EBSQ-VASC) exams⁴⁵⁻⁴⁷ and are a vital step in learning a system of audit. Regular discussion with mentors assisted by examining the logbooks helps to appraise and to define shorter-term aims for the individual trainee. In this way, clinical commitments and timetables may be amended to ensure adequate exposure to a prescribed minimum number of tasks or procedures. Perhaps numbers and proficiency attained on models and simulators should also be included. Logbooks also allow scrutiny of that institution—documenting the extent and variability of experience gained within a single surgical unit. This allows the trainers and trainees to focus on deficiencies and plan for provision of training posts.⁴⁴

Task Specific Checklists. These more structured assessments were designed to introduce some objectivity and reproducibility to technical skills assessment. This has been documented but since then there have been further refinements.⁴¹ Applied to the performance of a distal anastomosis these tasks may include: suitable positioning of the patient and limb, correctly placed incision, safe and cautious dissection of the target vessel (with identification of related anatomical structures and use of appropriate instrumentation), successful control of the vessel with atraumatic techniques, administration of anticoagulants, appropriate arteriotomy, accurate and even suture placement according to the requested technique, lavage and flushing of the anastomosis and release in appropriate order. While they are highly content specific (assess knowledge of the procedure⁴⁸), studies have shown procedure specific checklists to have only moderate-poor validity in surgical skills assessment.⁴⁹

Global Rating—OSATS (Objective structured assessment of technical skill). Was specifically introduced by the Department of Surgery in Toronto for use in surgical skills assessment.^{50,51} It is a Global Ratings Scale and its components are based on checklists but they examine overall technical skill rather than each step performed. It assesses the candidates respect for tissues, instrument handing, suture handing and apparent knowledge of the procedure to give a cumulative score reflecting overall proficiency⁵¹

(Table 2). It has since been extensively validated in a number of centers.⁵² It has been applied to tasks performed in the laboratory setting and with direct observations in the operating theatre. It can also be applied to video analysis of footage taken of any procedure,⁵³ thus the assessors remain blinded to the candidate.

Procedural Rating Scales. These objective scores take many aspects from checklists but allow for better validation of the scores that are awarded. For each of the tasks a scale of performance from poor to excellent is utilized to award appropriate points (Table 2). The importance of some tasks may be weighted with a system that allocates greater scores for more crucial components. The allocation of points per task in this matter allows the fine-tuning of the rating scale to increase its validity. Whilst OSATS assesses general constructs of performance, Reznick and others have demonstrated procedural rating scales demonstrate high inter-rater reliability in the hands of expert surgeons.⁵⁴ Ongoing studies have demonstrated the construct validity of these scales and concurrent validity with Global Rating Scales.¹²

Clinical Outcome Indicators. Clinical outcomes (such as complications) are poor indicators to employ given the time lag in the presentation of many of the complications of vascular surgery. This produces difficulties in rating performance of units in large institutions over many years, let alone a single surgical trainee over the short period of training within a specific surgical unit. By using models and simulators several relevant outcomes can be objectively measured. Some parameters that can be objectively measured include: overall time to complete a task, total number of movements, leakage of fluid from an anastomosis and the diameter of the lumen after completion of an anastomosis.^{55,56} These may prove to be more accurate than or at least complimentary to Global Ratings Scores.

Motion Sensors and Movement Analysis. The Imperial College Surgical Assessment Device (ICSAD)^{19,57,58} has been developed at St Mary's in London to objectively record the operator's hand movements. These small electromagnetic emitters can be attached to instruments or placed within the surgical gloves of the operator and the relative positions in three dimensions derived as a set of coordinates. The coarse digital output, which reflects tremor and non-purposeful movements, can be filtered to obtain objective measures for the total number of purposeful movements and the total path length the hands take during a prescribed task. Economy of hand movements correlates highly with other assessment tools.⁵⁷ Measurements of hand movements during a simulated

Table 2. Example of a procedure rating scale.

Graft-to-artery anastomosis					
Candidate no:					
Date:					
Assessor:					
Imperial College evaluation of 1		2	3	4	5
procedure-specific					
Vessel control	1	2	3	4	5
	Poor use of slings or clamps. Inadequate positioning of vessel		Poor use of slings or clamps. Inadequate positioning of vessel		Excellent control of vessel through superior positioning and use of slings/clamps
Arteriotomy	1	2	3	4	5
	Poor handling of scalpel. Jagged arteriotomy or posterior wall damage		Competent		Superior handling of scalpel. Lean arteriotomy
Vessel preparation	1	2	3	4	5
	Poor use of Potts scissors. Graft opening wrong size or shape		Competent		Exhibits familiarity with technique. Graft opening of appropriate size and shape
Graft shaping	1	2	3	4	5
	Poor. Did not know how to fashion the graft		Graft shaped adequately		Graft shaped to maximise anastomotic cross-sectional area. Clearly superior
Anastomosis	1	2	3	4	5
	Unfamiliar with all techniques of graft anastomosis. Poor needle handling		Competent use of parachute or other technique to anastomose vessels		Looked comfortable and familiar with technique. Superior anastomotic technique
Vessel handling	1	2	3	4	5
	Handled vessel excessively		Competent		Atraumatic, rarely mishandled native vessel
Vessel wall apposition	1	2	3	4	5
	Poor apposition of vessels		Reasonable wall apposition		Excellent vessel wall apposition
Quality of finished product	1	2	3	4	5
	Excessive stenosis of vessel. Sutures placed in haphazard manner. Likely to leak		Some stenosis of vessel however reasonable intima-intimal apposition. Suture placement adequate		Maximal cross-sectional area achieved. Neat suture line. A clearly superior end-product. Looked secure

A procedure rating scale specifically designed for assessment of procedural knowledge and technical skill displayed during the performance of a distal end-side anastomosis (simulated or live-surgical task). Points are awarded according to the visual scale for each specified category and the total is calculated. A similar scale was employed during a trial assessment for the EBSQ-VASC examinations held in Istanbul in September, 2002.

laparoscopic task also correlate well with the experience of the operator,⁵⁹ the operator's choice of more efficient techniques⁶⁰ and the speed at which the operator consciously undertakes the task.⁶¹ This is now being applied to vascular patching and anastomotic tasks.

Computer (Virtual Reality) Simulators. These laboratory-based learning devices can have their capability extended a step further, employing them a tool with which assessment of technical competence is carried out.⁶² Computer scoring systems can be incorporated in their design and objective scoring systems can be applied by real-time observers or following review of video-tape footage. They allow objective assessment of a surgeon's ability to ensure optimal surgical performance.¹¹ Assessment of efficiency of hand movement, number of correctional sub-movements and the time required to complete tasks using the *MIST Virtual Reality laparoscopic simulator* has identified trained surgeons as better performers than those who were untrained. This demonstrates the construct validity of the technique. Surgeons who completed a training course improved (compared with control surgeons), suggesting that many of these psychomotor skills are learned.¹²

Many simulators are in different phases of development and the quality of the visual and tactile interfaces varies considerably. Haptic feedback, whereby the weight, consistency or resistance in a tissue is fed back to the operator by motors within the simulator, is currently being refined on a number of simulators. This will add to their fidelity, improving face validity for trainees and content validity for assessors. Although they are clearly proving themselves as useful training aids, the current simulators need further development to become a reliable form of assessment.⁶³

Virtual Operating Room Simulations. The department of surgical technology and oncology at Imperial College, St Mary's Hospital, London has a fully reproduced operating room which is used for the study of not only technical competence but also aspects of communication, teamwork and efficiency.^{64,65} Simulations can be run for both anaesthetic and surgical trainees and role-playing assistants contribute to the realism of the simulated task. The multi-channel video footage of the procedure, surgeon's movements and interactions within the theatre are digitally recorded, as are the (simulated) patient's physiological parameters and other objective variables such as elapsed time and number of movements. The recorded footage can be reviewed with the trainee as a means of feedback, which from early reports seems enormously valuable.⁶⁶

Applications for Infringuinal Bypass Surgery

We have subdivided bypass procedures into five integrated steps that can be individually addressed with various approaches to training and assessment, in a variety of settings (Table 3).

Knowledge of Indications and Operative Plan

Surgical decision-making is learned through experience or exposure in meetings. However, the crucial issues can be addressed in a more analytical manner:

1. Does the patient need an operation?
2. Does the patient understand the consequences of the operation?
3. Do my results for that procedure justify intervention?

Learning Methods. This is best addressed in an open forum by a review of clinical cases with X-rays. Preferably a quorum of surgeons and trainees encouraging discussion and justification of management strategies.

The operative plan should be discussed in an open and informal manner during clinical case conferences, unit meetings and in the operating theatre prior to commencement of the operation. Principles can be offered in a more formal setting by course such as the Education Masterclass run by the VSSGBI at their Annual Scientific Meeting and the Higher Surgical Training Courses offered by the RCS (England).

Assessment. Oral operative case presentation and *viva voce* examinations are a tried and tested form of examining surgical knowledge. Reznick et al. at The University of Toronto have developed a comprehensive examination for senior surgical residents, PAME (Patient Assessment and Management Evaluation). This examination is complementary to OSATS but evaluates clinical management skills. Computerised simulations can be introduced to train and assess the entire operative approach and plan.

Anatomical Approach

The textbook descriptions are never perfect. Knowledge of a technique requires clear and accurate anatomical understanding.

Training Techniques. Cadaveric workshops provide excellent insights into anatomical dissections and understanding of surgical planes. These are offered to surgeons and trainees at all stages but opportunities should not be squandered. Cadaveric limbs provide excellent opportunities for training on dissection of

Table 3. Training methods available.

Component	Technique	Setting
Indications and operative plan	Case reviews Preoperative discussion	Seminars/meetings Seminars/meetings
Anatomical approach	Cadaveric workshops Dissection on amputated limbs	Anatomy laboratory Mortuary
Setup for anastomosis	Cadaveric workshops Amputated limb dissections Plastic body models	Anatomy laboratory Mortuary Skills lab/courses
Anastomosis technique	Bench top exercises (simple) Plastic body-models Cadavers (access difficulties)	Surgical skills lab Skills lab/courses Mortuary
Quality control	Direct visual inspection (Opening anastomosis specimen) Angioscopy Intra-operative Doppler and duplex Clinical follow-up with duplex	Skills lab/courses Operating theatre Operating theatre Outpatients

crural or ankle vessels and anastomoses with autologous vein or discarded prosthetic conduits. Body models still lack the accuracy to simulate the subtleties of accurate anatomical dissection through tissue planes.

Assessment. Models lack the anatomical accuracy to effectively evaluate this component. In future virtual reality simulators may be able to assist in this but the tactile feedback of real tissue is invaluable and is not widely incorporated in simulators at present. Assessment by mentors during live cases still remains the most valuable but more objective rating scales should be applied and this can be carried out in a blinded manner using video footage.

Setup for the Anastomosis

Setting up the operative field is of paramount importance and there is no place for hurried preparation. Facilitation of adequate exposure, retraction and assistance for a technically demanding distal anastomosis is paramount. Attention to details of exposure can make the anastomosis itself look easy.

Training Techniques. This requires familiarity with the difficulties of access and practice with the setup technique. This is readily obtained with quality plastic limb models; practice on amputated limbs and during cadaveric workshops. Positioning of rubber slings, packs and retractors are techniques that are enormously important to surgeons at all levels.

Assessment. Objective Global Rating Scales and Procedure Rating Scales can be applied by assessors to live exercises or pre-recorded footage.

Anastomosis Technique

Vitaly important to all vascular surgery but crucial in

the realm of small calibre and diseased vessels encountered in femoro-distal bypass surgery.

Training Techniques. The basics can be taught on simple bench-top jigs with discarded prosthetic materials. Progression from the bench-top to body models and cadavers will help provide a more realistic feel and tolerances of human tissues. Trainees need to familiarise themselves with loupes for better vision, since these are mandatory during distal revascularisations.

Assessment. Task specific checklists and Global Rating Scales can be applied.

Quality Control (Outcome Assessment)

One of the most crucial elements of the procedure involves some form of intraoperative assessment of the effectiveness of the revascularisation. Such an assessment provides objective feedback to the trainee immediately after completion. Methods employed vary from institution to institution and trainees should gain experience in as many and varied techniques as possible.

Training and Assessment Techniques. Each of these modalities can be used as a self-evaluation exercise and objectively scored by examiners for assessment purposes.

Direct Visual Inspection. This can also be undertaken in workshops (bench-top models) and with plastic body models and cadaveric exercises. Removing and cutting the specimen open allows inspection of suture placement and spacing and defects in the intima-to-intima apposition and narrowing or tethering within the host vessel.

Objective Measures. Connecting the model specimens within water circuits also allows some assessment of 'haemostasis' (measuring the leak-rate of fluid

across the suture-line) and the flow rate (determined by outflow resistance)⁶⁸ through a small calibre anastomotic model. Model specimens can also be cast and the luminal dimensions measured from that cast. All are objective measures that allow assessment and feedback of the technical success to the trainee.

Conclusion

Vascular surgeons can improve training methods to enable trainees to learn more effectively. There is a wide range of workshop, laboratory and seminar-room based methods available for teaching all aspects of infrainguinal bypass surgery. Assessment of technical aptitude in the diverse range of skills and techniques required for arterial revascularisation has become possible using a number of standardized and well-validated techniques. In the future there will be increased reliance on computer-based virtual reality simulations. Many of these methods will be relied upon by trainees and surgeons who will increasingly require evidence of competence.

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