Current trends in microsurgical education – review of types of training and skill assessment instruments

Współczesne kierunki nauki mikrochirurgii – przegląd metod kształcenia i narzędzi oceny nabytych umiejętności

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Abstract

Microsurgery became an essential part of various specialties. Hand replantation, vascular free flap reconstruction, and cerebral bypasses are impossible to conduct without mastering microsurgical skills. Currently, the gold standard of microsurgical training is the course with living models during which participants perform basic microsurgical procedures under the supervision of an experienced tutor. However, due to high cost of training and ethical issues new training models, which reduce the usage of living animals, appeared. Widespread availability of personal digital technology has caused creation of new types of in-house training using training videos and non-living models. The key factor of microsurgical training is assessment of obtained skills. For this reason, several evaluation scores have been developed: from comprehensive questionaries filled by experienced tutor to simple scales suitable for self-assessment. In this article authors review current types of microsurgical training and scores for assessment of the microsurgical competence.

Key words: microsurgery, microsurgical education, microsurgical training, assessment scores

Streszczenie


Słowa kluczowe: mikrochirurgia, nauka mikrochirurgii, narzędzia oceny
**Introduction**

Microsurgery became an essential part of various specialties[1-3]. Microvascular and nerve reconstructions lay at the basis of many surgical procedures. Proper understanding of visual feedback, control of physiologic tremor, better instrument design, and development of surgical skills with better precision is important for optimal surgical results. Development of this extensive range of technical skills requires constant, repetitive training. The aim of the simulation is to place trainees in an environment that replicates, as much as possible, experiences to be encountered in the operating room. Several authors report strong impact of prior training with simulation models on treatment results: complication rate and finally patient outcome [4, 5]. The most known way of improvement of microsurgical skills is a multiple-day microsurgical course. As the courses provide a planned curriculum, dedicated instructors and living models the average cost are up to 2000 dollars. High cost of training, the necessity of long travel, legal and ethical issues related to usage of living animals significantly limits its availability [6]. Furthermore, there is no agreement concerning standardization of microsurgical training and way of assessment of obtained skills. For that reason, various more-cost efficient simulation models that aim to reduce the number of animals without compromising training quality had been developed. In this article, authors review current types of microsurgical training and scores for assessment of the microsurgical competence.

**Types of microsurgical training**

**Living Models**

Most microsurgical courses are four-six days, with time under microscope ranging from 35 to 40 hours [6].

The curriculum of most courses worldwide includes training on living models like rat abdominal aorta or femoral artery. They offer the opportunity to practice dissection and perform vascular anastomosis, flaps and finally reconstructions techniques, and organs transplantations. Living models not only provides conditions similar to human tissue but also provide excellent feedback of anastomosis patency [7].

Moreover, practice with anesthetized live animals simulates the conditions during real procedures in the operating theatre. One of the advantages is chance to develop non-technical competencies, including psychological stress management, fatigue, and improvement of a decision-making process during the procedure.

For those reasons living models are considered as the gold standard model for microsurgical training [8].

However, training with living models is significantly challenging. Microsurgical labs which would like to use living models have to fulfill specific ethical regulations and be familiar with the animal anesthesia. These requirements significantly increase the cost of microsurgical courses and drive ethical reasons [6]. Therefore, accessibility of this type of training is reduced especially among younger doctors in low-income countries [6, 9, 10].

Limited availability of living models forced surgeons to create many non-living training models.

**Non-living models**

There are various types of non-living models, included cadaveric human and animal models like human placenta, chicken wing or thigh, porcine coronary vessels, and synthetic like rubber gloves and artificial vessels (Table 1). The chicken thigh model was validated in several studies as it closely reflects arterial anastomosis in the human hand in terms of both – size of the anastomosis and required tissue care [10-12]. Furthermore, non-living models are cost-efficient and do not interfere with ethical issues, but provide no feedback about the anastomosis function, blood flow, or tendency to thrombosis [7].

For that reason, chicken models are considered to be suitable model for initial microsurgical training that can correctly track the learning curve of basic skills [11]. Rodriguez et. al proposed a basic training curriculum that uses only non-living chicken models and was validated by UWOMSA (Western Ontario Microsurgery Skills Acquisition/Assessment) [12, 14].

<table>
<thead>
<tr>
<th>Synthetic</th>
<th>Animal</th>
<th>Cadaveric Human</th>
<th>Study</th>
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<tr>
<td>Rubber gloves</td>
<td></td>
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<td>Malik et al[10]</td>
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<tr>
<td>Surgical gauze</td>
<td></td>
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<td>Demirseren et al.[28]</td>
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<tr>
<td>Flower petal</td>
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<td>Volovici et al.[29]</td>
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<tr>
<td>Chicken wing</td>
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<td>Rodriguez et al.[12]</td>
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<tr>
<td>Chicken aorta</td>
<td></td>
<td></td>
<td>Ramachandran et al.[30]</td>
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<tr>
<td>Chicken thigh</td>
<td></td>
<td></td>
<td>Rodriguez et al.[12]</td>
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<tr>
<td>Chicken leg</td>
<td></td>
<td></td>
<td>Cifuentes et al.[31]</td>
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<tr>
<td>Porcine coronary arteries</td>
<td></td>
<td></td>
<td>Hong et al.[32]</td>
</tr>
<tr>
<td>Porcine kidney</td>
<td></td>
<td></td>
<td>Dos Reis et al.[33]</td>
</tr>
<tr>
<td>Human placenta</td>
<td></td>
<td></td>
<td>Alcala et al.[34]</td>
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<tr>
<td>Human cadaver flaps</td>
<td></td>
<td></td>
<td>Carey et al.[35]</td>
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<tr>
<td>Fresh human cadaver</td>
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<td>Carey et al.[35]</td>
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Application of prior training with non-living models allowed to reduction of living models between 50% to 90% without compromising the quality of training [7, 15].

Summary of characteristic of living and non-living models were detailed in (Table 2).

Table 2. Advantages and disadvantages of living and non-living models

<table>
<thead>
<tr>
<th>Model</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Living models</td>
<td>– Presence of circulation</td>
<td>– High cost of training</td>
</tr>
<tr>
<td></td>
<td>– Immediate feedback of anastomosis patency</td>
<td>– Ethical issues</td>
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<td></td>
<td>– Living tissue with physiology</td>
<td>– Complicated maintenance</td>
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<td></td>
<td>– Development of non-technical skills</td>
<td>– Need legal permission</td>
</tr>
<tr>
<td></td>
<td>– Conditions close to real surgery</td>
<td>– Need expert supervisor</td>
</tr>
<tr>
<td>Non-living models</td>
<td>– Low cost of training</td>
<td>– No physiology and circulation</td>
</tr>
<tr>
<td></td>
<td>– Reduction of live animals</td>
<td>– No direct feedback of anastomosis</td>
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<td></td>
<td>– Suitable for in-house self-training</td>
<td>– Inability to develop</td>
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<td></td>
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<td>– technical skills</td>
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Self-training vs training with supervision

The growing availability of online training resources such as YouTube videos, non-living models and affordable surgical instruments created a new type of in-house laboratory training.

This type of training is a realistic, cheap, and reproducible tool to help the trainee to maintain already obtained skills. In-house microsurgical training is believed to improve confidence and the microsurgical psychomotor skills required to perform the actual microsurgery, regardless of case type. Moreover, there are some training models that successfully use tablets, cameras end other magnifying devices instead of surgical microscopes [16-18].

In a randomized-control study, Malik et al. showed that in early stage of microsurgical skill acquisition, home training using jeweler’s microscope or iPad produces similar results to laboratory-based training with a microscope[10]. Similarly, preliminary results of an ongoing randomized trial on big groups of participants suggest that on a basic level in-house self-training with instructional videos may be non-inferior to training with a dedicated supervisor during regular course.

It should be emphasized that self-learning on non-living models works as an intermediate stage to consolidate basic skills prior to embarking on more advanced exercises in the living model. This allows for multitasking and increased efficiency within the operating room.

Nevertheless, training with an experienced supervisor remains a gold standard. This type of training is especially beneficial on a higher level of microsurgical proficiency with living animals. Study by. Paladino et al. reported better improvement of vessel patency and workflow among students with expert instructor training on a rat model. Since self-directed training develop mainly dexterity and technical skills, the expert’s feedback makes opportunity to reflect on the mistakes and find the reason for the anastomosis failure in a more complicated scenario.

Assessment scales

Improvement of microsurgical skills is significantly impeded without structured assessment. Atkins et al. showed that not all trainees are able to achieve the required competency level during the course [19]. Moreover, 25% of the basic microsurgical courses include no evaluation method to test microsurgical competence[20]. Scoring methods vary from complicated Global Rating Scales (GRS) which evaluates each aspect of surgical performance to final-product scales like Anastomotic Lapse Index (ALI) and Microsurgical Anastomosis Rating Scale (MARS10) which focus on technical aspects, quality, and function of end-product. Validated scales were detailed in (Table 3).

Table 3. Validated Microsurgical Assessment Methods

<table>
<thead>
<tr>
<th>Study</th>
<th>Assessment Method</th>
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<tr>
<td>Satterwhite et al.</td>
<td>Global Rating Scales:</td>
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<tr>
<td>Temple et al.</td>
<td>SmaRT</td>
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<td>Martin et al.</td>
<td>UWOMSA</td>
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<tr>
<td>Chan et al.</td>
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<tr>
<td>Ghanem et al.</td>
<td>Anastomosis Lapse Index</td>
</tr>
<tr>
<td>Stogowski et al.</td>
<td>Microsurgical Anastomosis Rating Scale</td>
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<tr>
<td>Starkes et al.</td>
<td>Time to complete the anastomosis</td>
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</table>

Global Rating Scales

The assessment of the surgical skill is a difficult task. Several rating scales have been developed and validated to facilitate objective assessment. However, there is no widely accepted global standard for evaluation instruments.

Global Rating Scales (GRS) were introduced to measure participants’ progress by standardized assessment instruments [21, 22]. In this type of assessment performance of the trainee is evaluated by direct observation by the expert microsurgeon who use specific comprehensive questionnaire. The pioneering GRS was OSATS (Objective Structured Assessment of Technical Skills). It comprises of a checklist and global rating scale (Likert scale 1-5) [23]. It assesses various aspects of surgical performance: respect for tissue, time and motion, instrument handling, knowledge of instruments, proper use of an assistant, flow of the procedure, as well as forward planning and the knowledge of specific procedures. However, the scale does not account for the time taken for the procedure or the surgical product.

Second widely used is SmaRT (Stanford Microsurgery and Resident Training) [24]. It consists of 9 categories: instrument handling, respect for “tissue,” efficiency, suture handling, suturing technique, quality of knot, final product,
operation flow, and overall performance. The strong point of this scale is ability to differentiate between the performance of novices and experts.

The third most known GRS is UWOMSA (University of Western Ontario Microsurgical Skills Acquisition/Assessment). It assesses skills in the 2 modules: anastomosis module which scores preparation, suturing and end anastomosis product and knot-tying module which assesses knot quality, instrument handling and workflow efficiency. Similarly to SmART, total score correlated with the level of expertise, additionally higher UWOMSA score corresponds with shorter time of task completion [14].

Although most of the Global Rating Scales are well-validated and have noticeable effect on improvement of microsurgical scales its usage is significantly limited. All GRS are complicated, time-consuming and require external assessment by the senior experienced surgeon. Hence, they are unable to apply to self-learning [25].

**Final product scales**

For the advanced courses on living models detailed and reliable tests are essential, however, a basic microsurgical course on non-living models requires a cheaper test that is easier to conduct and is more time efficient. There are some scoring systems mainly dedicated to specific training models. Currently, there are only two rating scales that are not related to a particular model and are suitable for assessment on the most of non-living models [26, 27].

First is a widely used is the Anastomosis Lapse Index (ALI). The scale was developed as the end-product evaluating tool for microsurgical anastomosis on non-living models such as a chicken leg or cryopreserved rat aorta. Evaluation is performed by opening the vessel and identification of 10 specific anastomotic errors in suture regularity, architecture, and spacing. The number, frequency, and type of performed errors correlate with the level of microsurgical competence divided on three categories: Novice (ALI>6), Intermediate (ALI 3-6), Expert (ALI <3) [27].

Similarly, the newly developed Microsurgical Anastomosis Rating Scale (MARS10) aims at self-assessment of end-product giving points from 0 to 2 in five categories, which describe suture spacing, bites sizes, suture distance from the incision, knot tying, and patency of the anastomosis. The scale precisely shows the individual’s rate of improvement and areas which need to be corrected. The great advantage of this instrument it can be use with success during in-house self-training. Another advantage of MARS10 is that evaluation of the anastomosis can be done remotely by the more experienced surgeon through the photo of the external and internal part of the vessel after cutting it open [26].

Both scales include parameters that are considered to have a crucial influence on anastomosis patency and tendency to thrombosis. However, they have not been yet validated on living models, so the true correlation between its score and anastomosis patency is not established. It is important to note that for that reason those scales should be used only for the evaluation of technical aspects of anastomosis performance. Prediction of anastomosis success/failure based on those instruments should be avoided [26, 27].

**Conclusion**

Several microsurgical simulation models have been described in literature. The training on the living model with a supervision of an expert instructor remains a gold standard. It allows the participant to reach a higher level of microsurgical competence in the shorter time. Simultaneously self-training on non-living models provides sufficient growth of microsurgical skills on a basic level. Currently, there is no widely accepted consensus of accessing microsurgical skills. Several rating scores are used. Its criteria of microsurgical excellence are significantly diversified. Future studies should establish gold standard for microsurgical assessment the and true impact of prior microsurgical training on performance in the clinical setting during real procedure.

**References**


