Hand Surgery and Rehabilitation 38 (2019) 353–357

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

Original article

Benefits of using the "Micro-Clock" to evaluate the acquisition and maintenance of microsurgery skills

Intérêt pédagogique de la « Micro-Montre » pour l'évaluation de l'acquisition et du maintien des compétences en microchirurgie

N. Kharouf [a,b], H. Cebula [c], S. Cifti [a,d], I. Talon [a,e], F. Séverac [f], N. Bahlouli [g], S. Facca [g,h,*]

[a] *Inserm UMR 1121, Université de Strasbourg, 11, rue Humann, 67000 Strasbourg, France*
[b] *Faculté de Chirurgie Dentaire, Université de Strasbourg, 8, rue Sainte-Elisabeth, 67000 Strasbourg, France*
[c] *Service de Neurochirurgie, Hôpital de Hautepierre, Hôpitaux Universitaires de Strasbourg, 1, avenue Molière, 67200 Strasbourg, France*
[d] *Service de Chirurgie ORL, Hôpital de Hautepierre, Hôpitaux Universitaires de Strasbourg, 1, avenue Molière, 67200 Strasbourg, France*
[e] *Service de Chirurgie Infantile Viscérale, Hôpital de Hautepierre, Hôpitaux Universitaires de Strasbourg, 1, avenue Molière, 67200 Strasbourg, France*
[f] *Laboratoire de Biostatistique et Informatique Médicale, ICube UMR 7357, Hôpitaux Universitaires de Strasbourg, 67091 Strasbourg cedex, France*
[g] *ICube, Université de Strasbourg, CNRS, Département de Mécanique, équipe MMB, 2-4, rue Boussingault, 67000 Strasbourg, France*
[h] *Service de chirurgie de la Main, SOS main, Hôpital de Hautepierre, Hôpitaux Universitaires de Strasbourg, 1, avenue Molière, 67200 Strasbourg, France*

ARTICLE INFO

Article history:
Received 16 January 2019
Received in revised form 25 September 2019
Accepted 30 September 2019
Available online 4 October 2019

Keywords:
Evaluation
Microsurgery
Microsurgical skills
Simulation
Educational tool
Micro-Clock

ABSTRACT

This study was done using an educational tool called the "Micro-Clock", which was inspired by Chan's "round-the-clock" training model. The Micro-Clock consisted of a surgical sponge on which 12 sewing needles were configured in the shape of a clock. The subjects were asked to thread a small suture through the eyelets as quickly as possible. Steadiness and instrument manipulation were evaluated during each trial and graded from 1 to 3. The execution time was measured in seconds. Fifteen instructors did the Micro-Clock test once in order to validate this tool's ability to assess the skills of qualified microsurgeons. Next, nine students, who were enrolled in a microsurgery diploma program, did the test nine times during the program to measure their progression and to evaluate their mastery and execution speed. There was no significant differences among the three instructor sub-groups (residents, assistants and senior surgeons) in their steadiness, instrument manipulation and execution time. When the students performed the Micro-Clock test, there was a significant improvement in movement fluidity as well as the execution time between the first and ninth test. Nevertheless, the execution time did not improve further after the fourth test. The Micro-Clock is a useful and reliable tool for teaching microsurgery skills and testing the maintenance of skills in qualified microsurgeons.

Mots clés :
Évaluation
Microchirurgie
Compétences microchirurgicales
Simulation
Modèle d'entraînement
« Micro-montre »

RÉSUMÉ

Un outil pédagogique: la «Micro-Montre» inspirée du test «Round-the-clock» a été utilisée pour cette étude. La « Micro-Montre » a permis de mesurer la progression des apprenants en microchirurgie par l'évaluation de scores et de durées de tests, mais aussi les compétences des chirurgiens déjà diplômés en microchirurgie. Quinze moniteurs (divisés en 3 sous-groupes) ont réalisé une fois le test «Micro-Montre». Neuf étudiants d'un Diplôme Universitaire de techniques microchirurgicales ont effectué 9 fois le test «Micro-Montre» durant leur entraînement. Dans les 2 groupes, la stabilité et la manipulation des instruments ont été évaluées à l'aide un score de 1 à 3. La durée d'exécution du test a été mesurée en secondes. Tous les résultats ont été traités par des études statistiques. Concernant les moniteurs, on ne constatait pas de différence significative entre les 3 sous-groupes (internes, assistants et seniors) quant à l'évaluation de la stabilité, la manipulation des instruments ou la durée d'exécution du test. Concernant

* Corresponding author at: Service de chirurgie de la Main, SOS main, Hôpital de Hautepierre, Hôpitaux Universitaires de Strasbourg, 1, avenue Molière, 67200 Strasbourg, France.
E-mail addresses: sybille.facca@unistra.fr, sybille.facca@gmail.com (S. Facca).

https://doi.org/10.1016/j.hansur.2019.09.007
2468-1229/

les étudiants, on observait une amélioration significative de la proportion de mouvements fluides dans le temps pour la stabilité et la manipulation des instruments, et une amélioration du temps écoulé entre le premier et le dernier test. On ne constatait pas de différence significative au-delà du 4e test quant à l'évaluation la durée d'exécution. Cet outil «Micro-Montre» s'avère utile et validant à la fois pour l'enseignement de la microchirurgie et pour tester le maintien des compétences par les microchirurgiens qualifiés.

1. Introduction

Surgical practice is increasingly focused on patient safety. To accomplish this, initial training with simulators and continuing education of surgeons are becoming more important. Good mastery of surgical skills requires tools for learning the skills, but also for evaluating a surgeon's mastery of these skills over time.

For microsurgery, the learning program has been divided into levels 1 to 4 [1]. The "classical" teaching of microsurgery techniques occurs at level 3 [1,2] and consists in performing vascular and nerve micro-anastomoses on an animal model (typically rats). It has been shown that preliminary training on non-living models (level 2) [3,4] helps us to comply with the 3R rules of animal experimentation (replacement, refinement, reduction) [5–7]. The other advantages of these level 2 models (plastic tubes, noodles, worms, etc.) are their ease of use, low cost and sterility (in some cases).

Our study of the new "Micro-Clock" tool, which was inspired by Chan's "round-the-clock" training model [8], had three goals:

- evaluate its relevance for measuring students' progress;
- "sanction" or define a standard that allows a surgeon to move to the next level;
- evaluate the skills of surgeons who already hold a microsurgery diploma.

2. Materials and methods

2.1. Materials

We set up two groups. Group A was made up of 15 microsurgery instructors, all holders of a microsurgery graduate diploma: 5 residents, 5 assistants and 5 senior surgeons. Only one person was ambidextrous. Group B consisted of 9 students (all right-handed) with no microsurgery experience, who were learning microsurgical techniques during an intensive 2-week microsurgery course leading to a graduate diploma.

Our Micro-Clock tool was available as a kit to be assembled: 12 size 8 sewing needles with an eyelet, round surgical sponge, sponge holder (Fig. 1a). Once the sponge was placed on its holder, it looked like an oblong clock, 3.4 cm in diameter. The 12 needles were placed on the sponge in a standard 12-hour clock configuration (Fig. 1b). However, so that all the needles were in a three-dimensional space but still in the same visual field, they were placed at three different heights: the four needles at 12, 3, 6 and 9 o'clock were placed 2.3 cm above the sponge; the four needles at 1, 4, 7 and 10 o'clock were placed 2.0 cm above the sponge; the four needles at 2, 5, 8 and 11 o'clock were placed 1.9 cm above the sponge (Fig. 1c).

The microsurgical instruments used in this task were a needle holder and dissecting forceps. The suture used was a 30-cm long colored 10-0 monofilament (Surgipro™, Covidien) with attached 5.5 cm long 1/2 curved needle. A standard teaching microscope with base was used with 6.5 × optical magnification in order to view the 12 needle eyelets in the same visual field (Fig. 1d). The time needed to pass the suture through all 12 eyelets was measured with a timer.

3. Methods

Before starting, all participants watched a film showing how the test is performed (https://moodle3.unistra.fr/). To perform the test, the surgeons loaded a microneedle on their needle holder. When the timer was started by the rater, the surgeons used the microscope's view to pass the needle and suture through the first eyelet at 12 o'clock. The suture was then passed through next eyelet going clockwise (for right-handed and ambidextrous subjects) until the 12th needle was reached at 11 o'clock. The timer was stopped once the subject had successfully threaded all 12 needles. If the surgeon dropped the microneedle, it had to be reloaded in the needle holder before continuing. If the suture broke or was lost, or if the microneedle was twisted, bent or broken, the incident was recorded, and the test restarted with the timer reset at 0.

For group A, the test was done only once. For group B, the test was done nine times. The students started their microsurgery training by performing the test once (Test 1), then they trained on level 2 simulators (plastic tubes, Japanese noodles, other simulators) and repeated the test between each step (Tests 2, 3, 4), before training on an animal model, for a total of 17 steps (Fig. 2). During the learning phase of microsurgery on rats, the students repeated our test four times (Tests 5, 6, 7, 8). The final test (Test 9) was done on the eve of the final examination.

A grading system based on the "Round-the-clock" model [8] was applied to all the tests in the two groups. Thus, three parameters were evaluated: steadiness and instrument handling on a scale of 1 to 3 (Table 1) and the execution time in seconds. Two senior raters who held a microsurgery diploma (instructors who have evaluated students for many years) evaluated each test.

Quantitative asymmetric variables were described by their median and first and third quartile values. The Gaussian nature of the distribution was evaluated graphically and using the Shapiro–Wilk test. The variables were compared between the three sub-groups (residents, assistants, senior surgeons) of Group A using the Kruskal–Wallis test. Qualitative variables were described by their counts and percentages, then compared using Pearson's χ^2 test or the Fisher test, depending on the sample size. The execution time was analyzed using a mixed-effects gamma regression model to take into account the repeated nature of the testing in Group B. Multiple comparisons between the different tests were adjusted using Holm's method. Steadiness and instrument handling over the various tests was analyzed using a mixed-effects gamma regression model. The results are presented as an odds ratio (OR) with 95% confidence intervals (CI). A P value < 0.05 was considered statistically significant. The statistical analysis was carried out using R software (version 3.2.2., R Core Team, 2015).

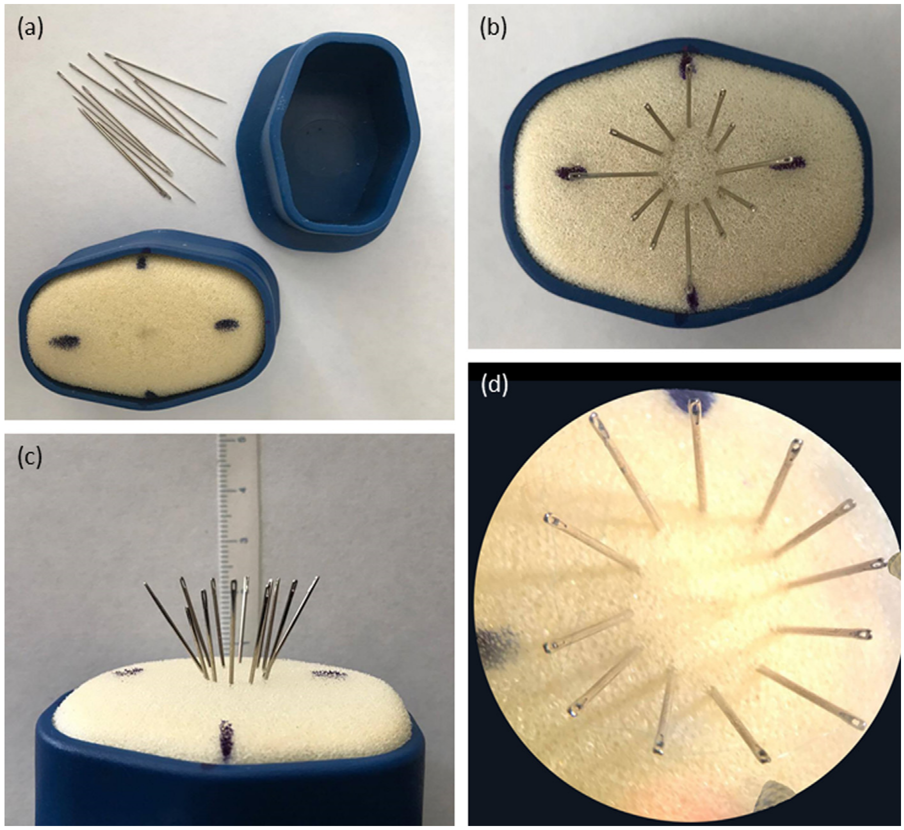

Fig. 1. The "Micro-Clock" training tool consists of 12 sewing needles, a surgical sponge and a sponge holder (a). The "Micro-Clock" is shaped like a clock face, 3.4 mm in diameter (b). Layout of the 12 needles with the eyelets set at various heights (1.9 cm, 2.0 cm, 2.3 cm) on the "Micro-Clock" (c). View of the 12 needle eyelets with 6.5 × optical magnification (d).

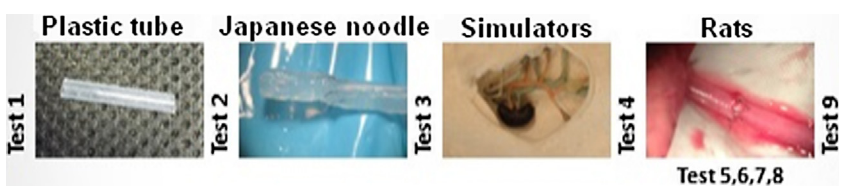

Fig. 2. Sequencing of the cycles and tests with the "Micro-Clock" in group B.

Table 1
The three items used to grade steadiness and instrument manipulation.

Steadiness	
1	Frequent trembling
2	Occasional trembling
3	Fluid, controlled movements
Instrument manipulation	
1	Clumsy, repetitive movements/inappropriate use
2	Good use but stiff/occasional clumsiness
3	Fluid movements without stiffness or clumsiness

4. Results

In Group A, the microsurgery instructors had a median execution time of 158 seconds (122; 200) (Fig. 3). No suture or needle breakage occurred. There was no significant difference between the three sub-groups in the execution time ($P = 0.160$). There was also no significant difference in the steadiness ($P = 1$) or instrument handling ($P = 1$) scores (Table 2). However, the majority of the senior surgeons' tests were graded as "3" (80% for the two items).

For Group B, the execution speed improved during their training ($P < 0.001$). There was a mean of 1.5 instances of suture or needle breakage per student; however, all occurred before test 3. There was a large decrease in execution time from Test 1 to Test 2 ($P = 0.014$) and from Test 3 to Test 4 ($P = 0.004$). There was no significant decrease beyond Test 4. At Test 9, the median time was 120 seconds (100; 140), thus a 77% improvement from their Test 1 time (Fig. 4). Similarly, there was a significant improvement over the nine tests in the movement steadiness (OR: 2.98 [1.74–5.13], $P < 0.001$) (Table 3) and instrument manipulations (OR: 3.60 [1.86–6.99], $P < 0.001$) (Table 3).

5. Discussion

Learning of microsurgery techniques in France is being redesigned given the reforms of the 3rd cycle of medical studies, cross-disciplinary specialized training in hand surgery, and also in the context of French and European regulations on animal experimentation [5,6]. Simulation using level 2 models is becoming the key step in the initial learning or even the maintenance of technical skills in microsurgery. Several level 2 models [3,9–11] have been developed and are being increasingly

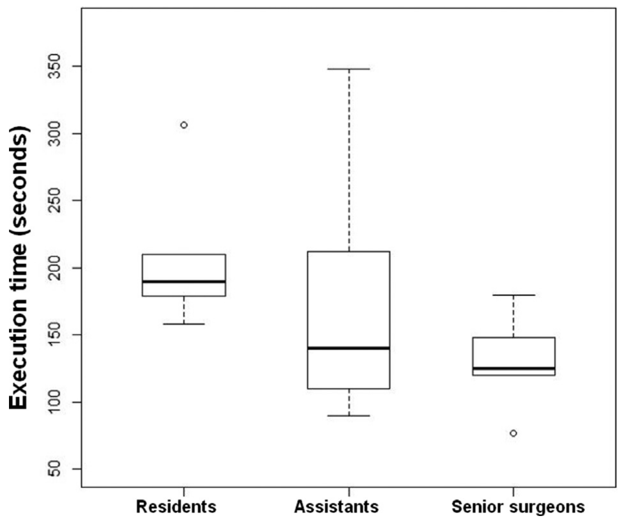

Fig. 3. Execution time in seconds for group A, which was divided into three sub-groups: residents, assistants, senior surgeons.

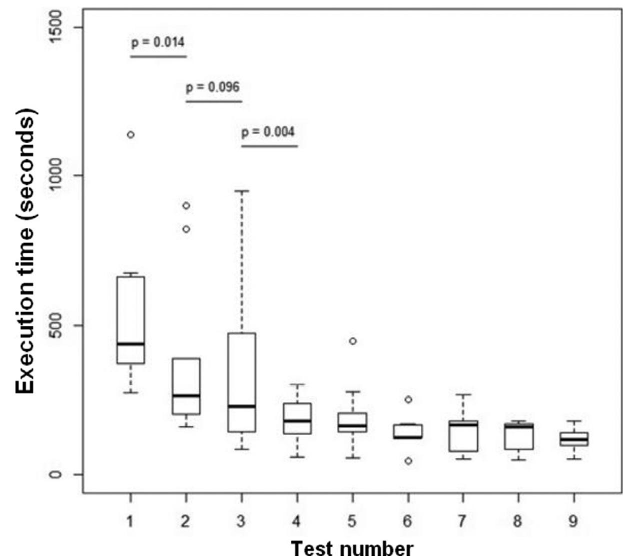

Fig. 4. Execution time in seconds for group B (9 tests).

Table 2
Distribution of the steadiness and instrument manipulation scores in group A (instructors).

Steadiness	Residents	Assistants	Senior surgeons
Level 1	20%	20%	0%
Level 2	20%	0%	20%
Level 3	60%	80%	80%

Instrument manipulation	Residents	Assistants	Senior surgeons
Level 1	0%	20%	0%
Level 2	40%	20%	20%
Level 3	60%	60%	80%

used in various graduate diploma programs in France, before moving on to animals. Starting with the principle of preliminary steps at the start of the learning phase on animals, but also keeping in mind the evaluation of microsurgery practice acquisition and maintenance, we sought to develop an educational tool for this evaluation. This tool had to be simple, suited to microsurgery techniques, reproducible (to homogenize assessments) and be a valid teaching aid. This led us to develop the Micro-Clock tool. First, we had to standardize this clock in a trial phase that lead to clear description of the materials required and reproducible set up by all the raters (Figs. 1a–c). This clock is especially useful for evaluating microsurgery, as the small needle eyelets can only be crossed by microneedles, while the specific arrangement of the needles in space (clock diameter, inter-needle distance and eyelet height) gives test a three-dimensional element. The three parameters used by Chan et al. (execution speed, steadiness and instrument manipulation) in their "round-the-clock" training model can be used to evaluate the learning curves for microsurgery skills and dexterity [8].

Our tool was validated first with instructors (group A) then applied to students of microsurgery techniques (group B). Note that the effect of hand dominance was not verified, as there were no left-handed surgeons in either group. In all likelihood, left-handed surgeons would need to perform the test counterclockwise, for the test to be valid for them.

The instructors (group A) had a median test speed of 158 seconds, with no differences between sub-groups. Nevertheless, since the residents rarely practice microsurgery in patients, their lack of experience was associated with slower times and worse scores than the assistants. Similarly, the senior surgeons had the fastest execution times and best scores.

In Group B, the test was done nine times on a very specific schedule (Fig. 2). Significant improvements in execution speed were found twice (end of 1st test and end of 3rd test) during the level 2 simulation training [3]. There was a significant improvement in the percentage of fluid movements over time for steadiness and instrument manipulation. Thus surgical performance improves gradually with practice on simulators [12–14]. This preliminary step before learning on rats is vital and cost-effective, making it easier to comply with 3R rules [6].

Of course, there were intra-individual and inter-individual differences between learners in our study. We noticed that when

Table 3
Distribution of the steadiness and instrument manipulation scores in group B (students in a microsurgery graduate diploma program).

Steadiness									
Level	1	2	3	4	5	6	7	8	9
1 & 2 (%)	100	88.89	55.56	44.44	33.33	22.22	22.22	11.11	0
3 (%)	0	11.11	44.44	55.56	66.67	77.78	77.78	88.89	100

Instrument manipulation									
Level	1	2	3	4	5	6	7	8	9
1 & 2 (%)	88.89	88.89	77.78	66.67	33.33	11.11	33.33	11.11	0
3 (%)	11.11	11.11	22.22	33.33	66.67	88.89	66.67	88.89	100

the test was done at the end of the day after microsurgery training, the scores and execution times were worse. Thus we recommend performing this test early in the day. Lastly, a student had to learn to master his actions, be fast and control the manipulations of his needle and suture. We defined thresholds to allow a student to go from level 2 [3] to level 3 [1,2]: execution time under 180 seconds, steadiness score of 2 and instrument manipulation score of 2.

If the median execution time is compared between the two groups (9th test and final test for group B), we see that the students had a better median time (120 seconds) than the instructors (180 seconds). However, the senior surgeons who regularly perform microsurgery had a median time of 125 seconds, which was markedly faster than that of the residents (190 seconds) and the assistants (140 seconds) (Fig. 3). Since the median time for all the instructors was 180 seconds, we can used 180 seconds as a threshold above which microsurgery practice is not sufficient and for which training must be resumed, at least on microsimulators.

6. Conclusion

The Micro-Clock is valid and useful tool for teaching microsurgery skills and testing the mastery of procedures by qualified microsurgeons. The 180-second threshold appears to be a good threshold for students to move from the simulation phase to the animal learning phase. This threshold also appears to be the upper limit for restarting microsurgery training for those who do not have a regular microsurgery practices.

Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Liverneaux PA, Hendriks S, Selber JC, Parekattil SJ. Robotically assisted microsurgery: development of basic skills course. Arch Plast Surg 2013;40:320–6.
[2] Shurey S, Akelina Y, Legagneux J, Malzone G, Jiga L, Ghanem AM. The rat model in microsurgery education: classical exercises and new horizons. Arch Plast Surg 2014;41:201–8.
[3] Prunières GJ, Taleb C, Hendriks S, Miyamoto H, Kuroshima N, Liverneaux PA, et al. Use of the Konnyaku Shirataki noodle as a low fidelity simulation training model for microvascular surgery in the operating theatre. Chir Main 2014;33:106–11.
[4] Meier SA, Lang A, Beer GM. Polyurethane vessels for microvascular surgical training to reduce animal use. ALTEX 2004;21:135–8.
[5] Burden N, Chapman K, Sewell F, Robinson V. Pioneering better science through the 3Rs: an introduction to the national centre for the replacement, refinement, and reduction of animals in research (NC3Rs). J Am Assoc Lab Anim Sci 2015;54:198–208.
[6] Richmond J. The 3Rs–Past, present and future. Scand J Lab Anim Sci 2000;27:84–92.
[7] Festing MF, Baumans V, Combes RD, Halder M, Hendriksen CF, Howard BR, et al. Reducing the use of laboratory animals in biomedical research: problems and possible solutions. Altern Lab Anim 1998;26:283–301.
[8] Chan WY, Figus A, Ekwobi C, Srinivasan JR, Ramakrishnan VV. The 'round-the-clock' training model for assessment and warm up of microsurgical skills: a validation study. J Plast Reconstr Aesthet Surg 2010;63:1323–8.
[9] Kim DC, Hayward PG, Morrison WA. Training model for microvessel anastomosis. Microsurgery 1994;15:820–1.
[10] Cifuentes IJ, Yañez RA, Salisbury MC, Rodriguez JR, Varas JE, Dagnino BL. A novel perforator flap training model using a chicken leg. J Hand Microsurg 2016;8:17–20.
[11] Galmiche C, Hidalgo Diaz JJ, Vernet P, Facca S, Menu G, Liverneaux P. Learning of supermicrosurgical vascular anastomosis: MicroChirSim® procedural simulator versus Anastomosis Training Kit® procedural simulator. Hand Surg Rehabil 2018;37:20–3.
[12] Price J, Naik V, Boodhwani M, Brandys T, Hendry P, Lam BK. A randomized evaluation of simulation training on performance of vascular anastomosis on a high-fidelity in vivo model: the role of deliberate practice. J Thorac Cardiovasc Surg 2011;142:496–503.
[13] Ilie VG, Ilie VI, Dobreanu C, Ghetu N, Luchian S, Pieptu D. Training of microsurgical skills on non-living models. Microsurgery 2008;28:571–7.
[14] Aurich LA, Silva Junior LF, Monteiro FM, Ottoni AN, Jung GS, Ramina R. Microsurgical training model with non-living swine head. Alternative for neurosurgical education. Acta Cir Bras 2014;29:405–9.