Relevance of a simulation model to microsurgery for military surgical residents

Ammar GHABI (ammar.ghabi@hotmail.fr)
École du Val-de-Grâce: Ecole du Val-de-Grace
Alexandre SABATE FERRIS
École du Val-de-Grâce: Ecole du Val-de-Grace
Georges PFISTER
École du Val-de-Grâce: Ecole du Val-de-Grace
Marie Pauline CHAPON
École du Val-de-Grâce: Ecole du Val-de-Grace
Josette Legagneux
Agence Generale des Equipements et Produits de Sante: AGEPS
Madeleine HARION
CHU Bicêtre: Hopital Bicetre
Laurent MATHIEU
HIA Percy: Hopital d'Instruction des Armees Percy

Research

Keywords: Initiation, Microsurgery, Military, Simulation

Posted Date: May 25th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-551087/v1

Abstract

Introduction

Microsurgical training is an asset for military orthopedic surgeons who frequently treat hand or nerve injuries in external operations. The objective of this study was to evaluate a microvascular surgery simulation model intended to prepare residents prior to their enrolment in conventional degree training.

Materials and Methods

An experimental study was conducted to evaluate technical progress and satisfaction of military surgical residents using a model based on Japanese noodles with four tests of increasing difficulty. Objective endpoints included: instrument handling, distribution and quality of stitches, duration of anastomoses and responses to the Structured Assesment of MicrosurgerySkill (SAMS) self-assessment questionnaire were also analyzed.

Results

Nine residents from different specialties participated in the study. The quality of their anastomoses and their average satisfaction were significantly increased between the first and the last session: respectively 7.2 / 15 versus 10.7 / 15 ($p < 0.05$) and 37.5 / 70 versus 47.5 / 70 ($p < 0.05$). Conversely, the average operating time decreased significantly over the sessions (92 min versus 52 min, $p < 0.001$).

Conclusions

This simulation model seems to constitute a satisfactory initiation to microsurgery which could limit the use of the animal model. It could also be included in the continuing education of military surgeons who perform microsurgery only occasionally in external operations.

Introduction

The teaching of microsurgery is still based on animal models, which is the only way to faithfully replicate real operating conditions, in particular the difficulties of dissection and manipulation of the walls of micro-vessels [1]. On the other hand, initial training in the handling of instrument and anastomosis techniques can be carried out by means of simulation. Many models have been developed and evaluated in recent years with the aim of limiting the use of animal models due to ethical and financial reasons [1–3].

Such simulation models could be useful for the initial and continuing education of military orthopedic surgeons, who are frequently called upon to repair vessels or nerves in external operations [1, 4, 5]. In the French Army Health Service, the validation of a university degree in microsurgical techniques is thus part of the initial training of orthopedic residents [5]. Prior initiation and regular training on a simulation model would allow them to better develop their technical capacities, dexterity and self-control [6]. Such a model could also be used to maintain the skills of senior surgeons who do not have regular practice of microsurgery in their daily activity in their country.

We have therefore developed a microsurgical simulation model for military surgical residents that complies with the 3R principle: Reduce the number of animals in experiments, Refine the methodology used and Replace animal models [7]. The objective of this study was to evaluate the relevance of this model. Our hypothesis was that the majority of participants would rapidly improve their performance without using the animal model.

Materiel And Methods

Study population

An experimental study was conducted among surgical residents assigned to the French Military Health Service Academy, Ecole du Val de Grâce, Paris. Included were residents from all specialties who had not yet training in microsurgery. Excluded were residents who had already been enrolled in a university degree in microsurgery.

Experimental protocol

The aim was to simulate the performance of various types of microvascular anastomoses over four training sessions. The simulation model was based on Japanese noodles of the *konnyakushiratakі* type as described by Prunières et al. [8]. Sutures were performed using standard microsurgical instruments (needle driver, dissecting forceps, double and single clamp) using surgical magnifiers with 3.5x magnification (YEARSUN, China) and 10.0 nylon thread.

Each session followed the same protocol and was supervised by a qualified microsurgery instructor:

1. The participant adjusted his magnifiers after explanation and demonstration by the instructor (Fig. 1A);

2. Each noodle was pierced with an intravenous catheter to provide visible and uniform light [8];

3. The anastomosis was described by the instructor with the help of an explanatory diagram, then the suture was started after internal understanding of the objectives of the session;

4. The amount of time taken to perform the anastomosis was measured and the handling of the instruments evaluated by the monitor.

At the end of each session, the instructor checked the permeability and quality of the anastomosis while the participant completed a self-assessment questionnaire.

Table I details the content of each of the sessions which consisted of various anastomosis of increasing difficulty: end-to-end anastomosis, end-to-side anastomosis and bypass with double end-to-end anastomosis (Fig. 1B) [9, 10].

Evaluation parameters

The anastomosis patency and the existence of leaks were assessed by injecting physiological saline through a catheter inserted proximally to the model [8].

The quality of the anastomosis was assessed from the inside after a longitudinal opening of the noodle (Fig. 1C). The assessment was based on an adaptation of the rating scale described by Chan et al. [11] according to three criteria scored from 1 to 5: instrument handling, repair of stitches and quality of stitches. The criteria for assessing the quality of the stitches were symmetry of the grip of the two edges, the tightness of the knots, the occurrence of a wall tear or a transfixing grip (Table 2).

The duration of the anastomosis procedure was also evaluated. It corresponded to the time elapsed between the positioning of the noodle on the double clamp and the section of thread during the last stitch. The amount of time was split in two during session 4 which included two anastomoses.

The subjective end-of-session self-assessment was performed using the SAMS (Structured Assesment of Microsurgery Skill) questionnaire, which has a high inter-rater reliability [11]. Fourteen criteria scored from 1 to 5 were assessed, with a maximum score of 70.

The primary endpoint was the comparison of scores obtained between the first and last session. The secondary endpoint included: 1) an independent assessment of each criterion in our rating scale; 2) a comparison of the participant's self-assigned scores; 3) a comparison of the length of completion time between anastomoses during the resident's advancement.

Statistical analysis

Data were collected using Excel software (Microsoft Corp., Redmond, WA, USA) to calculate means and standard deviations. Statistical analysis was performed using R software [12]. A p value <0.05 was considered statistically significant.

Results

Nine residents with an average age of 28 (range: 24–35) completed all four sessions. There were six orthopedic residents, two visceral surgery residents and an ophthalmology resident. Their advancement within their six-year training course was uneven: two were in their first year, three in their second year and three in their fourth year.

The anastomosis were permeable in all cases, with constant leaks more or less important depending on the quality of the anastomosis. Their quality was significantly increased between the first and the last session overall and for each of the three criteria evaluated (Table 3). The average length of procedure for complete anastomosis was 92 minutes (range: 60–115 minutes) during the first session versus 52 minutes (range: 40–70 minutes) during the last session. There was a significant decrease in operation duration over the sessions ($p < 0.001$, Fig. 2).

The average SAMS score was 37.5 37.5 (range: 28–45) during the first session compared to 47.5 (range: 37–58) during the last session. There was a significant increase in this score over the sessions ($p < 0.001$, Fig. 3). Twelve out of 14 criteria were significantly increased, but two had only a statistical tendency to increase: "atraumatic use of the needle" ($p = 0.069$) and "section of the thread" ($p = 0.052$).

Discussion

Numerous studies have been published in recent years in the field of experimental microsurgery in order to test various simulation models and alternative means of magnification under the microscope [1–3, 8, 11, 13]. The goal is always the same: to facilitate the transmission of microsurgical techniques while limiting costs and the use of animals. An ideal training model is a simple, reproducible and easily accessible tool that also complies with regulations [7]. To our knowledge, this study is the first to report the use of a microsurgical simulation model for military surgeons in training. Although many of them will not have daily practice of microsurgery, they will have to use these skills occasionally within forward surgical structures where hand wounds are frequent [5]. This work thus meets the need for training and regular practice of microsurgery for French military orthopedic surgeons.

With the suggested model, there is a significant improvement in the technical performance of residents over the sessions, both in terms of quality of anastomoses and in terms of speed of execution. These objective results, in association with a significant increase in the average SAMS score, provide reliable evidence of improvement of surgical skills by the participants [11]. The presence of an instructor and the constant increase in technical difficulty probably explain this rapid progression over the course of the sessions. This type of companionship is similar to that of traditional university training which has proven its efficiency [9,14]. In fact, our method is based on various studies in order to recommend a model adapted to the specific needs of military surgeons in terms of initial and continuing training [1, 8, 13].

The use of surgical magnifiers seemed obvious to us because it is often the only means of optical magnification available in external operations. They have been used to perform digital revascularization and nerve repair in many local injuries in forward surgical structures [5]. Magnifiers are also used by experienced microsurgeons for microvascular anastomoses and nerve repairs in their daily practice [15]. They are an easily accessible tool, outside of any university or hospital structure, relatively inexpensive, and adapted to the Japanese noodle model with a diameter of about 1mm. We haveshown that they can reliably perform anastomoses on the rat abdominal aorta, whose diameter (also about 1 mm) is comparable to that of digital arteries [1].

The konnyakushirataki noodle model was selected because of its availability, its very low cost and its close structure to the animal model [8]. However, although this noodle is suitable for learning how to handle instruments, it does not take into account the difficulties of suturing on real vessels. The assessment of patency and leakage could not be reliably assessed in this study. Pruniers et al. [8] point out that this model does not reproduce the arterial spasm of thrombosis, nor the platelet deposit that seals the anastomosis in the first few minutes. Unlike them, we did not use a dye in the saline, which could have facilitated the detection of some leaks. The other defects of this model lie in the noodle's low resistance and high porosity. As Pruniers et al. [8], we observed a large number of wall tears in the first sessions. However, parietal lesions became less frequent over the course of the sessions, indicating a progression of the criterion "atraumatic tissue manipulation". For all these reasons, we did not perform the Acland patency test [16], which we felt was hazardous and irrelevant. We were therefore forced to limit our objective assessment to instrument handling and the quality of the stitches. Despite these drawbacks, we find that this model is still suitable for microsurgical initiation before the animal model, and that it is an interesting alternative to more elaborate or more expensive models [17–19].

The other limitations of this study are related to the small sample size and its purely descriptive nature, without comparison to other simulation procedures, or to the reference training model of the rat. In spite of these limitations, our model allowed students to become familiar with the handling of microsurgical instruments in order to prepare them before transitioning on to the animal model, which remains mandatory for the moment. Its main advantage is easy access: any surgeon with magnifying glasses and a set of microsurgical instruments can use it to train alone in all circumstances, including during field deployments.

Conclusion

The proposed microsurgical simulation model appears to be relevant for the initial training of military surgical residents. It allows a fast technical advancement which is an excellent groundwork, and even a useful counterpart to classical training on animals. This simple and readily available tool could also be applied to the continuing education of military orthopedic surgeons who only occasional practice microsurgery during deployments.

Declarations

Acknowledgements

The authors thank Ms. Nathalie de Garambé (Société EligiX - statistical reporting, Paris, France) for her assistance in the statistical analysis.

Competing interests

None

Ethical Approval and Consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files.

Author's contributions

All authors participated in the drafting, critical revision, and approval of the final version of the manuscript

Author's information

Affiliation:

Clinic of orthopedics, traumatology and reconstructive surgery, Percy Military Hospital, 101 avenue Henri Barbusse, 92140 Clamart, France

Microsurgerylaboratory,SurgicalSchool,Agence Générale de Equipements et Produits de Santé - Assistance Publique des Hôpitaux de Paris, 7 rue du Fer à Moulin 75005 Paris, France

Pediatric department, Bicêtre French Hospital, 78, rue du Général-Leclerc, 94270 Le Kremlin-Bicêtre, France.

Department of surgery, French Military Health Service Academy, Ecole du Val-de-Grâce, 1 place Alphonse Laveran, 75005 Paris, France

Funding

None

References

1. Ghabi A, Amar S, Harion M, Legagneux J, Vignes J-L, Mathieu L. Microvascular anastomosis using loupes and smartphone magnification: Experimental study for application to limited-resource environments. *Hand Surg Rehabil.*2020;39:92 –8.
2. Abi-Rafeh J, Zammit D, MojtahedJaberi M, Al-Halabi B, Thibaudeau S. Nonbiological Microsurgery Simulators in Plastic Surgery Training: A Systematic Review.*PlastReconstr Surg.* 2019;144:496e–507e.
3. Javid P, Aydın A, Mohanna PN, Dasgupta P, Ahmed K. Current status of simulation and training models in microsurgery: A systematic review.2019;39:655–68.
4. Mathieu L,Levadoux M, Soucany de Landevoisin E, McBride T, Rigal S. Digital replantation in forward surgical units: cases report. *SICOT-J.*2018;4:9.

5. Mathieu L, Ghabi A, Amar S, Murison J-C, Boddaert G, Levadoux M. The state of microsurgical practice in French forward surgical facilities from 2003 to 2015. *Hand Surg Rehabil.*2019;38:358–63.
6. Vinagre G, Villa J, Amillo S. Microsurgery Training: Does It Improve Surgical Skills? *J Hand Microsurg.*2017;9:47–
7. Russell WMS, Burch RL. The principles of humane experimental technique. Methuen; 1959.
8. Prunières GJ, Taleb C, Hendriks S, Miyamoto H, Kuroshima N, Liverneaux PA, Facca S.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.
9. Legagneux J., Gilbert A. Apprentissage de la microchirurgie vasculaire. EMC (Elsevier Masson SAS, Paris), Techniques chirurgicales - Chirurgie plastique reconstructrice et esthétique, 45-025, 2007.
10. Pederson WC. Principles of microvascular surgery. Bone and soft tissue reconstruction. Chap. 47. In: Wolfe, Hotchkiss, Pederson, Kozin eds. Green's operative hand surgery. Sixth edition. Elsevier, Philadelphia, 2011 p 1553-1584.
11. Chan W-Y, Matteucci P, Southern SJ. Validation of microsurgical models in microsurgery training and competence: A review. 2007;27:494–9.
12. R Development Core Team (2005). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL: http://www.R-project.org.
13. Malik MM, Hachach-Haram N, Tahir M, Al-Musabi M, Masud D, Mohanna P-N. Acquisition of basic microsurgery skills using home-based simulation training: A randomised control study. *J PlastReconstrAesthet Surg.*2017;70:478–86.
14. Bergmeister KD, Kneser U, Kremer T, Harhaus L, Daeschler SC, Pierer G, et al. New concept for microsurgical education: The training academy of the German Working Group for Microsurgery of Peripheral Nerves and Vessels: Results of a 4-year evaluation. 2019;51:327–33.
15. Stanbury SJ, Elfar J. The use of surgical loupes in microsurgery. *J Hand Surg.* 2011;36A:154–6.
16. Acland RD. Signs of patency in small-vessel anastomosis. 1972;72:744–8.
17. Hüsken N, Schuppe O, Sismanidis E, Beier F. MicroSim - a microsurgical training simulator. *Stud Health Technol Inform.*2013;184:205–9.
18. Hayashi K, Hattori Y, Yii Chia DS, Sakamoto S, Marei A, Doi K. A supermicrosurgery training model using the chicken mid and lower wing. *J PlastReconstrAesthet Surg.*2018;71:943–5.
19. Lovato RM, Campos Paiva AL, Pesente FS, de Oliveira JG, Ferrarez CE, Vitorino Araújo JL, et al. An Affordable Stereomicroscope for Microsurgery Training with Fluorescence Mode. 2019; 130:142–5.

Figures

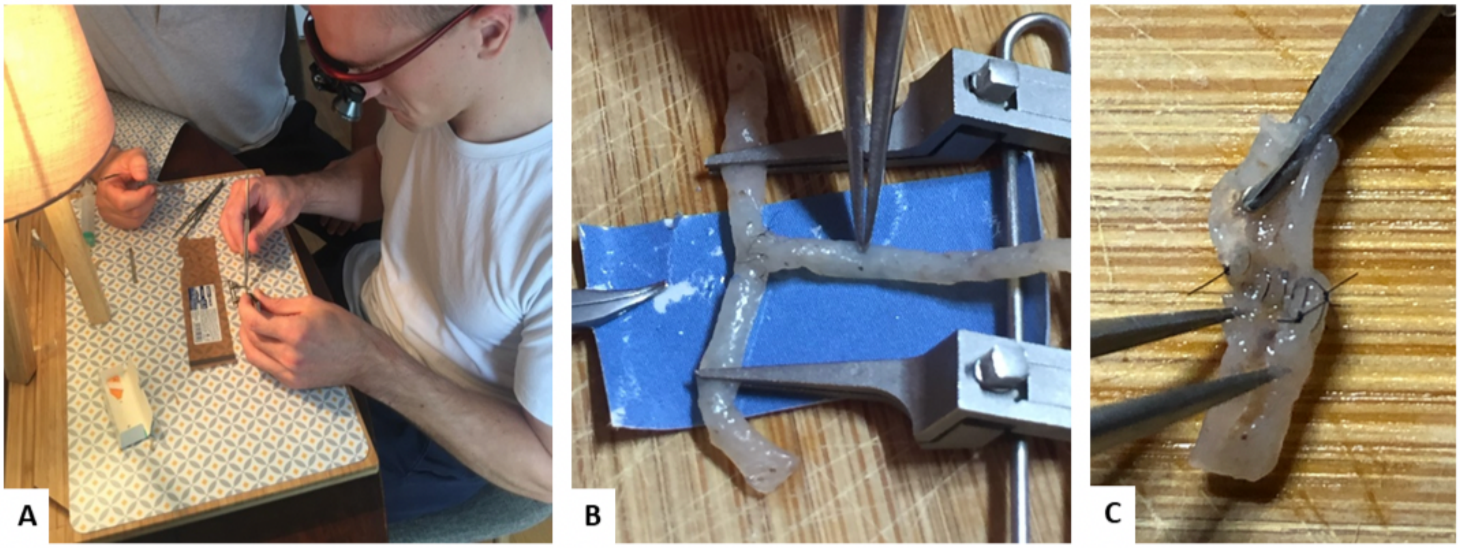

Figure 1

Photographs showing the working position of the participants (A), the performance of a lateral anastomosis (B) and the control of the anastomosis by the instructor at the end of the session (C).

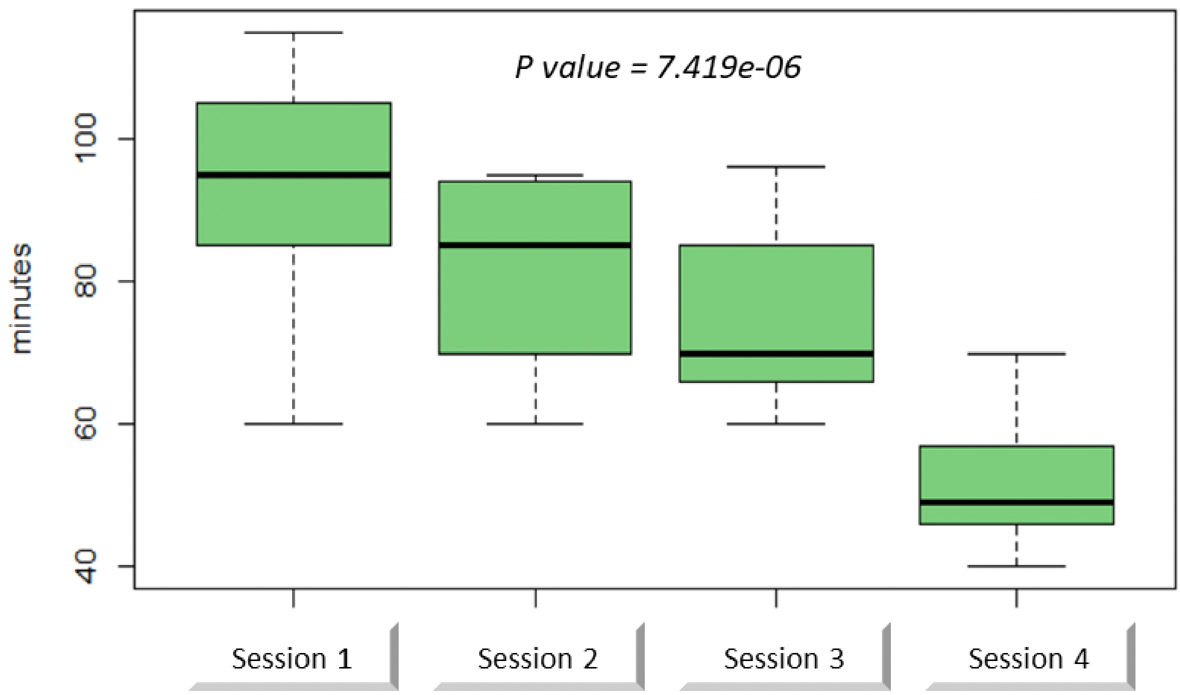

Figure 2

Anastomosis duration through sessions

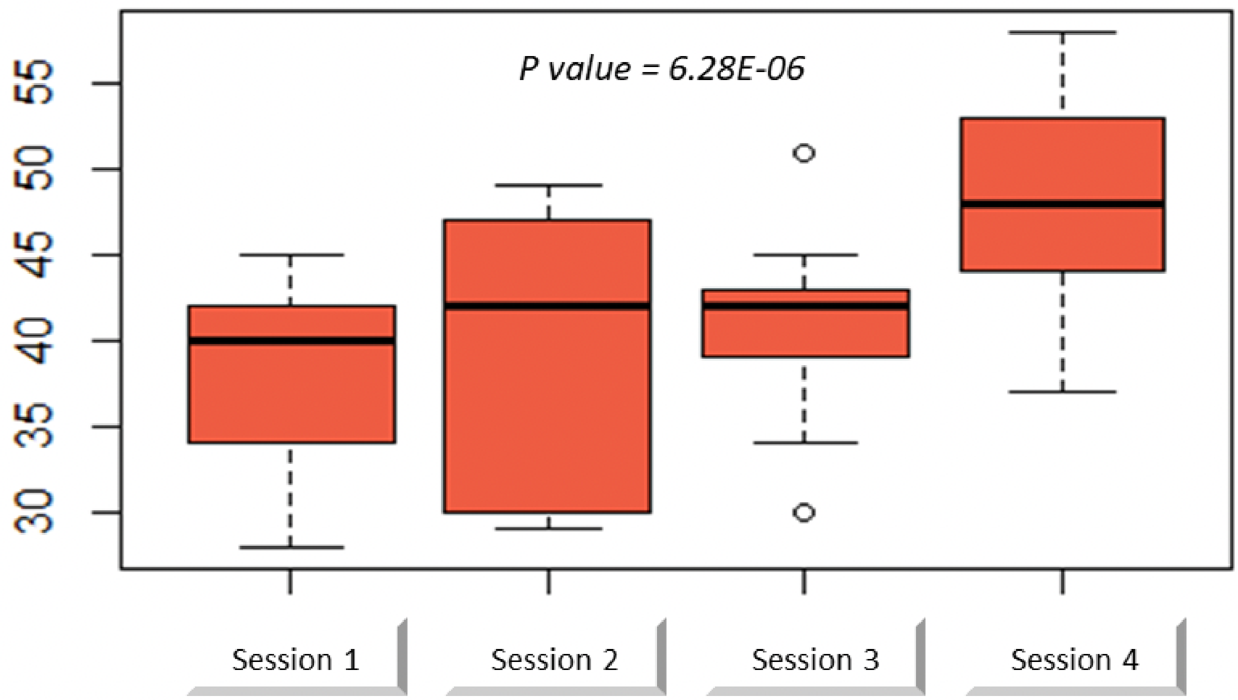

Figure 3

SAMS score through sessions [11]