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Original article

Does the repetition over a short time of a microsurgical suture improve its reliability?

La répétition sur un temps court d'une suture microchirurgicale permet-elle d'en améliorer sa fiabilité ?

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ABSTRACT

Our hypothesis was that immediate repetition of a microsurgery-suturing task will improve its execution and outcome. This was an experimental animal study. Ten surgeons were divided into two groups of five surgeons. Each performed two end-to-end carotid anastomoses on the same rat, one after the other. The anastomosis was evaluated by the surgeon and an instructor. The primary endpoint was permeability. The outcome was evaluated using an objective and subjective assessment grid yielding 1 to 3 points per item. The total scores for each of the 10 surgeons were used to compare the anastomosis of carotid 1 versus 2, using the ratings given by the surgeon and the instructor. Twenty anastomoses were performed, but 1 rat died intraoperatively, leaving 18 anastomoses for evaluation. No significant differences were found on the main endpoint of permeability, with all anastomoses being permeable. The surgeon's self-assessment was significantly better for the second carotid artery ($P = 0.05$), but this was not confirmed by the proxy assessment (instructor). The analysis by subgroups—morning versus afternoon—found the second carotid anastomosis was significant better in the self-assessment and proxy assessment for the morning group ($P < 0.001$, $P = 0.024$). There was no significant difference in clamping times. The immediate repetition of a microsurgical procedure seems to favor its execution, which leads us to propose that the more difficult or important anastomosis should be done after an easier or less important one during complex surgeries.
Level of evidence: 2B

Mots clés :
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RÉSUMÉ

L'hypothèse était que la répétition immédiate d'une suture microchirurgicale permettait d'en améliorer son exécution et/ou sa qualité. Il s'agissait d'une étude expérimentale animale. Dix opérateurs étaient répartis en 2 groupes de 5 opérateurs. Chacun effectuait 2 anastomoses termino-terminales de carotides sur le même rat, l'une à la suite de l'autre. Les sutures étaient jugées par l'opérateur et par un enseignant évaluateur. Le critère de jugement principal était la perméabilité. L'évaluation était faite grâce à une

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grille d'évaluation objective et subjective rapportant 1 à 3 points par item. Le total des notes pour chacun des 10 opérateurs permettait de comparer l'anastomose des carotides 1 et 2, via les notes attribuées par l'opérateur et l'évaluateur. Vingt anastomoses ont été réalisées, 1 rat est décédé en per-opératoire, soit 18 anastomoses évaluées. Aucune différence significative n'a été mise en évidence sur le critère principal de perméabilité, toutes étant perméables. L'autoévaluation mettait en évidence une différence significative en faveur de la seconde carotide ($p = 0,05$), non confirmée par l'évaluation de l'enseignant. L'analyse en sous-groupes, matin/après-midi, montrait une différence significative en faveur de la seconde carotide tant sur l'autoévaluation que sur l'évaluation par l'enseignant pour le groupe du matin ($p < 0,001$, $p = 0,024$). Il n'y avait pas de différence significative sur les temps de clampage. La répétition immédiate d'une procédure microchirurgicale semble favoriser son exécution, nous incitant à proposer de faire en seconde position une anastomose de difficulté ou d'importance supérieure.
Niveau de preuve. – 2B

1. Introduction

Microsurgery requires meticulous technique. The learning of microsurgery skills can be integrated directly in the specialty's training program [1], or it can be taught during dedicated microsurgery training courses [2]. This comprises practical training sessions in a laboratory setting on inert materials [3] and then in a living model [4]. The assessment of microsurgery skills is increasingly being done with objective evaluation criteria (hand movements, leaking of anastomosis, patency test) [5], which helps to optimize one's actions during a procedure in current practice.

The benefits of "immediate" repetition of a skill have been documented as improved performance during learning [6–8]. This concept has long been used at aircraft pilot training centers [9]. In current practice, repeating a procedure contributes to reducing the morbidity and mortality rate [10].

Generally in clinical practice, the microsurgical phase of a procedure is integrated and described in the surgical technique at a specific point in time. For example, in hand surgery, it is understood that bone fixation is first, then suture repair of tendons, followed by the microsurgical steps with arterial then venous anastomoses, followed by nerve repair and last, skin coverage [11]. However, the sequencing of the microsurgical anastomosis phase, especially when several anastomoses are needed, has not been defined.

The quality of a microsurgery task repeated immediately during the same procedure has never been studied. The aim of this study was to determine if immediate repetition of a microsurgical suturing task helps to improve it reliability, execution and quality.

2. Materials and methods

2.1. Study design

This was an experimental animal study, approved by our research ethics committee. All of the study-related procedures and observations were carried out on February 4, 2019 during the 6th day of a microsurgery graduate diploma course. The entire curriculum for this diploma was conducted over a 2-week period.

2.2. General procedures

The sample consisted of 10 surgeons from different specialties (plastic surgery, orthopedic surgery, maxillofacial surgery, neurosurgery, otorhinolaryngology) and with different experience levels who were participating in the microsurgery course. The students were divided into two groups of five surgeons; group 1 operated in the morning (8 am to 12 noon) while group 2 operated in the afternoon (1 pm to 5 pm). The first phase of each half-day consisted of a training session on an inert material (Konnyaku Shirataki noodle) [3]. The full procedure consisted of anesthetizing a rat, positioning it, dissecting the first carotid artery, performing arteriotomy and end-to-end micro-anastomosis, and then repeating the same procedure on the other side.

2.3. Anesthesia and surgical technique

Rats (female, Sprague Dawley, average 300 g) were provided by the animal husbandry center of the Angers University Hospital. Each surgeon was responsible for the anesthesia and dissection of their rat. For the surgery, a rat was placed in an induction chamber, which was filled with Isoflurane at 5 L/min. Once sedated, the rat was weighed to determine the optimal dose of anesthetic agent. A mixture of ketamine (100 mg/kg) and xylazine (10 mg/kg) was administered in bolus IP injection; a second injection could be done as needed during the procedure. Once its reflexes were suppressed, the rat was placed supine on a cork board, with its extremities held by elastic bands.

A single T-shaped incision (Fig. 1) was made to allow the two carotid arteries to be dissected and exposed. A transverse arteriotomy was done after the clamp was placed on the vessel. Anastomosis was done using microscopy, with each surgeon choosing their own magnification. Nonabsorbable 10-0 monofilament suture was used.

2.4. Assessment and endpoints

After the first end-to-end anastomosis (C1) was completed, it was evaluated by the student and the instructor. Subjective and

Fig. 1. T-shaped incision followed by end-to-end anastomosis.

DEXTERITY	Stability / Fluidity	Frequent trembling		1
		Occasional trembling		2
		Fluid movements		3
	Instrument manipulation	Clumsy, trouble placing needle on needle-holder		1
		Occasionally clumsy		2
		Precise movements		3
	Needles	Bent, detached, broken sutures		1
		Occasional damage to needle		2
		Economical use of sutures with intact needle		3
VESSEL PREPARATION	Dissection	Traumatic with damage to adjacent tissues		1
		Insufficient exposure of vessel		2
		Good exposure with circumferential release of vessel		3
	Clamping	Inappropriate placement		1
		Nearly perfect placement		2
		Optimal placement		3
ANASTOMOSIS	Manipulation of vessels	Traumatic		1
		Occasional damage to vessel wall		2
		Atraumatic		3
	Suture repair	Irregular points		1
		Nearly regular points		2
		Regular and correct point placement		3
ANALYSIS	Check before releasing clamp	Sutures not verified		1
		Good suture verification: 1 or more points modified		2
		Good suture verification: no additional points needed		3
	Permeability upon clamp release	None		1
		Localized leak or small stenosis		2
		Perfect		3
	Patency test	Poor procedure		1
		Inadequate procedure		2
		Good procedure		3

Fig. 2. CoTeMi grid (developed by Adeline Cambon Binder) used by the surgeon and the instructor to assess the procedure.

objective outcomes were assessed using a simplified grid derived from the CoTeMi grid described by Adeline Cambon Binder (http://www.edu.upmc.fr/medecine/pedagogie/memoire/Memoires_16/Memoire_Cambon-Binder) (Fig. 2) and inspired by the scale described by Chan [12]. Each item was graded as 1, 2 or 3 points. The same procedure was followed for the second anastomosis (C2).

2.4.1. Primary endpoint: permeability

The permeability of the anastomosis was determined with a patency test, upstream of the suture. The test was scored as either perfect, localized leak/small stenosis, or absent.

2.4.2. Secondary endpoints

The subjective assessment parameters, evaluated during and after the procedure, were scored as incorrect, correct or perfect. The following items were graded:

- dexterity (quality of movements, instrument manipulation, needle-induced damage);
- blood vessel preparation (quality of dissection, clamp positioning);
- anastomosis quality (regularity, manipulation and preservation of blood vessels during procedure).

The instructor recorded when the clamp was applied and when it was released, then calculated the clamping time.

2.5. Statistical analysis

The statistical analysis was carried out using R software (version 3.5.2, The R Foundation for Statistical Computing, Vienna, Austria). Since there is no published data on evaluating the progress made in microsurgery skills, all the subjects were

Table 1
Main endpoint: permeability (patency test).

	Self-assessment (student)		Proxy assessment (instructor)	
	Mean of differences	*P*	Mean of differences	*P*
All groups pooled	−0.1111 [−0.401; 0.1788]	0.430	−0.0556 [−0.4895; 0.3784]	0.790
Morning group	−0.1111 [−0.401; 0.1788]	0.430	0	1.000
Afternoon group	0.125 [−0.4108; 0.6608]	0.598	−0.125 [−1.167; 0.917]	0.785

Table 2
Evaluation of dexterity/preparation/quality/control.

	Self-assessment (student)		Proxy assessment (instructor)	
	Mean of C1–C2 difference	*P*	Mean of C1–C2 difference	*P*
Student 1[a]	0	1.000	0	1.000
Student 2[a]	−0.2 [−0.6524; 0.2524]	0.343	−0.4 [−0.7694; −0.0306]	0.037
Student 3[a]	−0.3 [−0.6456; 0.0456]	0.081	−0.3 [−0.6456; 0.0456]	0.081
Student 4[a]	−0.8 [−1.3643;−0.2357]	0.011	0	1.000
Student 5[a]	−0.4 [−0.7694;−0.0306]	0.037	−0.3 [−0.6456; 0.0456]	0.081
Student 6[b]	0.2 [−0.1016; 0.5016]	0.168	0.1 [−0.1262; 0.3262]	0.343
Student 7[b]	0.1429 [−0.2067; 0.4924]	0.356	0.1 [−0.4278; 0.6278]	0.678
Student 8[b]	0.4 [−0.2032; 1.0032]	0.168	0.5 [−0.2727; 1.2727]	0.177
Student 9[b]	−0.7778 [−1.2902; −0.2653]	0.008	−0.7 [−1.1828; −0.2172]	0.009
Student 10[b]	−0.3 [−0.7828; 0.1828]	0.193	−0.2 [−0.6524; 0.2524]	0.343

[a] Morning group.
[b] Afternoon group.

included. A paired Student's *t*-test was used to compare the mean values for the primary endpoint. The pairing was based on the carotid arteries. A value of $P < 0.05$ was considered statistically significant.

3. Results

3.1. Permeability

Only one anastomosis was not permeable (C2, Student 4) One rat died during the procedure. No significant difference in permeability was found between C1 and C2 (Table 1).

3.2. Dexterity/preparation/quality/verification

The total points assigned during the evaluation of C1 was compared for each student to the total assigned for C2 (Table 2). Three students felt they were better during C2, two of which had significantly improved according to the instructor's evaluation. The self-assessment was significantly better during C2 ($P = 0.005$), although this difference was not confirmed by the instructor's evaluation (Table 3). In the subgroup analysis (morning vs. afternoon groups), C2 was significantly better in the morning group in the self-assessment and the instructor's assessment (Table 3).

3.3. Clamping time

There was no significant different in the clamping time between C1 and C2, although the latter was somewhat shorter (Table 4).

4. Discussion

The aim of this study was to determine whether immediate repetition of a microsurgical suturing task improves its quality. Up to now, no study had been published on this topic. We found no significant difference in our primary endpoint (patency test), although there was a trend towards C2 being better, which would need to be confirmed on a study with more subjects.

Table 4
comparison of mean clamping time (in seconds) between C1 and C2.

	C1–clamping time	C2–clamping time	Mean of differences	*P*
$N = 9$[a]	39	29	7.78 [−1.4844; 17.04]	0.089

[a] One animal died.

As for the anastomosis quality, based on our criteria (dexterity, preparation, quality) [2,6,7], the surgeon felt that repetition was a significant contributing factor ($P = 0.005$), although the instructor did not confirm this finding. It turns out that the surgeon, who is always harder on himself, seems to underestimate the quality of the first anastomosis, while the instructor assigned more points to it. Conversely, the points assigned by the surgeon and instructor were the same for the second anastomosis. This difference in opinion highlights the difficulty of performing objective, reproducible assessments [10] of a manual procedure with a composite instead of a binary success criteria (yes/no, permeable/non-permeable anastomosis). It may be relevant to evaluate the trends in self- and proxy assessment of a 3rd consecutive anastomosis to objectively determine how the self-assessment changes.

Improvement in the quality of anastomosis execution was significant in the morning group, according to the surgeons and instructor. This finding highlights the fact that the success of a high-precision cognitive and motor skill is affected by the time of day in which it is done. One study showed an impact of the carbohydrate/protein ratio [13] of the first meal of the day, with it affecting short-term memory and the precision of tasks carried out [14].

Furthermore, there was no significant difference in the clamping time between C1 and C2 ($P = 0.089$). This can be explained in many ways, the most obvious being lack of statistical power. But the more likely reason is the surgeon's experience level, which had a noticeable impact on the difference between the two times during the same procedure [2]. A younger surgeon who is still in the learning phase, improves his manipulations and systematizes his actions during the exercise, thus his time improvement between C1 and C2 may be large depending on his personal learning curve [6]. Conversely, a more experienced

Table 3
Comparison of anastomosis quality between morning and afternoon groups.

	Self-assessment (student)		Proxy assessment (instructor)	
	Mean of C1–C2 difference	*P*	Mean of C1–C2 difference	*P*
All groups pooled	−0.2083 [−0.3521; −0.0646]	0.005	−0.12 [−0.2618; 0.0218]	0.096
Morning group	−0.340 [−0.527; −0.153]	< 0.001	−0.20 [−0.3722; −0.0278]	0.024
Afternoon group	−0.0652 [−0.2857; 0.1553]	0.554	−0.04 [−0.2694; 0.1894]	0.727

surgeon, whose actions and habits are already optimal and highly repeatable, will likely have consistent anastomosis time. This question could be answered by increasing our sample size and carrying out subgroup analyses by surgeon experience level.

The evidence of an impact, whether beneficial or not, of immediate repetition on a microsurgery procedure allows us to propose a strategy for performing multiple anastomoses, as is the case for re-implantations. In this scenario, the broad steps are already described in the literature; however, the sequence of microsurgery steps is not clearly set out. Feng Zhan [15] was the first to attempt to address this problem in 2002. He concluded that a short venous stasis after arterial anastomosis does not damage the flap's circulation, meaning that arterial suturing should be done first. Other authors have proposed that two teams work simultaneousness to optimize the procedure time [16]. In our practice, when several arterial and venous anastomoses are required, the sequence is determined by the surgeon. Our study found the second anastomosis was better than the first in the morning group. Clinically, when multiple anastomoses need to be done, it would be preferable to do the most important anastomosis after a less important one.

Moreover, based our findings and the literature, we continue to believe that microsurgery training must be repetitive and practical. For optimal, rapid progression [7], it must be conducted continuously over a compressed period of time [17]. The aeronautics industry integrated this concept many years again in their training [9]. Learning periods must be close together to minimize the forgetting curve described by Hermann Ebbinghaus in 1885, who established that things learned slowly are forgotten more quickly [18]. This training must consist of repetitive steps and actions that become more complex over time [17]. And it also must include reminders to consolidate learned skills, even during the career of an experienced surgeon [8].

Our study has several strengths: it was prospective, comparative and used a paired design. It had a short duration (one day) without missing data and the assessments were performed immediately after the procedure by the surgeon and instructor. This instructor was an experienced surgeon who has been the head of the microsurgery diploma program for many years, thus well-versed in observing and analyzing microsurgery procedures. One of its limitations is that a surgeon's objectivity during self-assessment can always be questioned. Another is the small size of the groups.

5. Conclusion

This prospective study evaluated the benefits of immediate repetition of a microsurgery procedure in terms of the effectiveness of the suturing and clamping time. It supports the validity and benefits of using repetition to achieve better results. Using self-assessment and proxy assessment of immediately repeated procedures could help surgeons determine their own optimal sequence for procedures requiring several anastomoses. Eventually, a larger scale study would allow us to draw objective conclusions about this microsurgical sequencing strategy.

Disclosure of interest

The authors declare that they have no competing interest.

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