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Stepwise training program: A novel practice schedule for laparoscopic suturing

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A R T I C L E I N F O

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Stepwise training
Practice schedule

A B S T R A C T

Purpose: We establish stepwise training program in which laparoscopic suturing is broken down to discrete steps. The purpose is to evaluate the learning outcomes of stepwise training program.
Materials and methods: Volunteer participants were enrolled from medical students and surgical trainees. Students took two courses of 2-h stepwise training, and a post-course (1st & 2nd) test was taken after each course; trainees took one course of stepwise training with a pre-course (1st) and a post-course (2nd) test. Attending surgeons took the test as control. Learning outcomes were assessed with laparoscopic suturing competency assessment tool (LS-CAT) and suturing time.
Results: There were 10 students, 8 trainees and 6 surgeon controls. Suturing time and LS-CAT scores significantly improved between the 1st and 2nd test ($p < 0.01$). In the both tests, suturing time and LS-CAT scores of students and trainees were similar. In the 1st test, surgeons had significantly better performance in suturing time and LS-CAT score than students and trainees; in the 2nd test, the LS-CAT scores of students and trainees were similar to the surgeon controls.
Conclusions: Stepwise program effectively enhances laparoscopic suturing skill for medical students and surgical trainees. Catch-up effect was demonstrated in medical students with stepwise training.

1. Introduction

The positive association between laparoscopic training and intraoperative performance has been well acknowledged [1]. It has

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been a regular phenomenon that a variety of simulations are designed to enhance trainees' learning outcome [2,3]. The In the program of Fundamentals of Laparoscopic Surgery (FLS) [4], the skill acquisition of laparoscopic intracorporeal suturing is an imperative milestone. It is necessary to have advanced level of hand-eye coordination to obtain this technique [5]. This hurdle can intimidate novices and hinder the progression of laparoscopic skills.

The ordinary practice schedule of laparoscopic suturing is to repeat the steps of needle loading, needle driving, and knotting serially. It is similar as serial practice in the field of motor skill learning [6]. The stepwise approach is proposed by decomposing a complex skill into small steps to practice [5]. Based on the advice, laparoscopic suturing can be divided into multiple steps with which the trainees will be able to practice one step in a block. Blocked practice is proved to be effective for motor skill acquisition [7].

Based on blocked practice, stepwise training program was organized for the medical students and surgical trainees in our institution. We hypothesize that stepwise program is effective in skill acquisition of laparoscopic suturing. The aim is to assess the outcomes of laparoscopic suturing training by using stepwise program.

2. Material and methods

2.1. Study design and setting

This is a prospective research conducted in our university hospital. The stepwise program and tests were undertaken on iSuture table designed by IRCAD-Taiwan (MedicalTek, Taiwan) (Fig. 1). The setup consisted of a laparoscopic platform with an internal-mounted high-definition camera, an incorporated adjustable screen and table, two needle holders (5 mm, 30 cm in length), and a suturing pad. Participants used a 3-0 polysorb™ (Covidien, GL-182) with a 20-cm length of thread during the test. The test was to accomplish a standardized task included an intracorporeal suture with a first double-throw knot and two single-throw knots on a suture pad.

Stepwise training program was a 2-h course with six blocks in this study. In each block, it started with a brief introduction of a specified step to practice for the block by showing a video clips (supplement). It moved to the next block based on the practice schedule. The practice schedule consisted of picking up the needle for 10 min, adjusting the angle of the needle for 20 min, driving the needle and pulling out the thread for 20 min, making a double-throw knots for 20 minis and knot tying for 20 min. Two participants

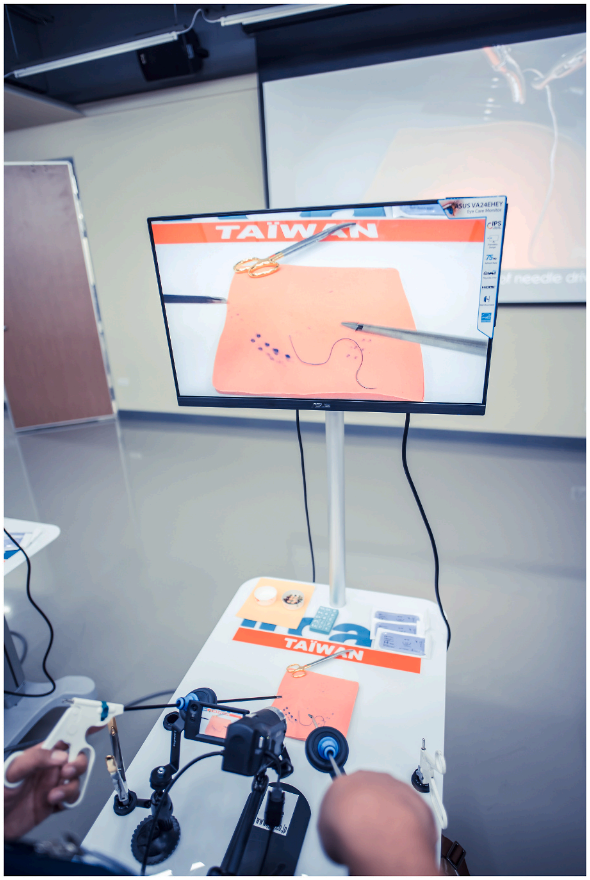


Fig. 1. iSuture laparoscopic training table.

took turn doing practice in one iSuture.

2.2. Participants

Three groups of participants, 1st-year clerkship medical students, resident/fellow trainees and attending surgeons, in the surgical department of our hospital were enrolled voluntarily. All the participants were requested to consent to the study.

The trial paths for the groups were shown in Fig. 2 and listed as below.

1. For students, a laparoscopic suturing tutorial video (https://www.youtube.com/watch?v=5HeQHDxDWQA) was provided to watch before the course. They took two courses of stepwise training. A standardized task was taken immediately after each course, which were two tests in total.
2. The trainees took single course of stepwise training. A standardized task was taken immediately before and after the course.
3. The attending surgeons did not participate in the course, and only took the standardized task for a control group.

2.3. Data collection and processing

The videos were recorded when the participants took the task. One specific attending surgeon was responsible for eliminating the test-taker identity and coding the clips randomly. When the process was accomplished, the videos were ready for assessment by raters.

2.4. Outcome assessment

The videos were reviewed and rated by two experts (HC & CW) with laparoscopic suturing competency assessment tool (LS-CAT) [8] individually without knowing the identity of the test-takers. The lower score of LS-CAT it is, the better skillset it stands for. We also checked the time required to finish the task.

2.5. Statistical analysis

Statistical analyses were performed with MedCalc statistical software version 20.011 (MedCalc Software Ltd, Belgium). Wilcoxon test was used to analyze the progression between 1st and 2nd test. Kruskal-Wallis test was used to compare the results between different levels of participants. The values were presented as median (interquartile range, IQR). A p value < 0.05 was deemed statistically significant. Pearson correlation coefficient (r) was conducted to evaluate the correlation between suturing time and LS-CAT scores. Inter-rater reliability was assessed by using Intraclass Correlation Coefficient (ICC) with 95 % confident intervals based on a mean-rating ($k = 2$), absolute-agreement, two-way mixed-effects model. Hedges' g was utilized for effect size by excel calculator. A g value of 0.2 indicates small effect size; 0.5 indicates medium effect size; 0.8 indicates large effect size.

2.6. Ethics

This prospective study is approved by TMU-JIRB (No. N202007002) and registered in ClinicalTrials.gov (Identifier: NCT0547436, https://clinicaltrials.gov/ct2/show/NCT05474365?cond=stepwise&draw=2&rank=1).

3. Results

There were 18 participants in total. Ten (7 males and 3 females) 5th-graded medical students and 8 (5 males and 3 females) surgical trainees, including 3 1st-year, 1 2nd-year, 2 3rd-year surgical residents, one junior and one senior surgical fellows, were enrolled. The medical students were all naïve to any laparoscopic experience. Six (all males) attending surgeons took the test as controls. The years of being attending surgeons ranged from 4 to 15 years with the median of 9.5 years. The results were demonstrated in Table 1.

The overall suturing times were 245 (202–428) and 203 (164–268) seconds for the 1st and 2nd test, respectively ($p < 0.01$). The overall scores were 21.3 (18.0–23.5) and 16.8 (14.0–20.0), respectively ($p < 0.01$). In the domain of "pick up needle", the scores were

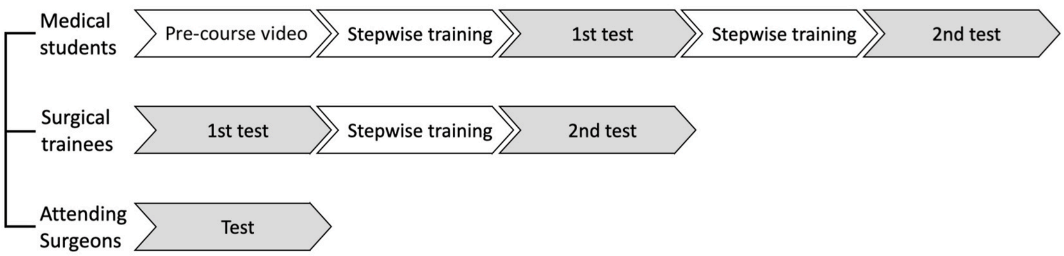


Fig. 2. Algorithm of the training courses and tests.

4.8 (3.0–7.0) and 3.5 (2.5–5.0), respectively ($p = 0.03$). In the domain of "pass needle through edges", the scores were 4.5 (4.0–5.0) and 3.5 (2.5–4.5), respectively ($p < 0.01$). In the domain of "create first double wind", the scores were 5.0 (4.5–6.5) and 4.5 (3.5–5.0), respectively ($p = 0.048$). In the domain of "knot tying", the scores were 6.0 (5.5–7.0) and 5.0 (4.5–6.0), respectively ($p = 0.02$).

In the group of medical students, the suturing times were 289 (202–411) and 202 (188–238) seconds for the 1st and 2nd test, respectively (p = 0.07) (g = 0.62). The overall scores were 22.0 (19.5–23.5) and 19.0 (15.0–21.0), respectively (p = 0.03) (g = 0.93). In the group of surgical trainees, the suture times were 227 (194–524) and 234 (149–304) seconds, respectively ($p = 0.04$) (g = 0.68). The overall scores were 19.8 (16.5–25.5) and 15.8 (13.3–17.0), respectively ($p = 0.02$) (g = 1.31).

Cross-group comparison between students, trainees and surgeons was performed. In the 1st test (Fig. 3a and b), the students required similar time to finish the task as surgical trainees did (g = 0.26); the scores were also similar between these two groups (g = 0.17). The surgeons had significantly lower suturing time (g = 1.72 and 1.12, respectively) and LS-CAT score (g = 2.23 and 1.54, respectively) in comparison to the students and trainees. In the 2nd test (Fig. 3c and d), the suturing times of the students and trainees were similar (g = 0.08), and significantly longer than that of the surgeons (g = 1.03 and 1.24, respectively). The difference between LS-CAT scores of the students and trainees did not achieve statistical significance (g = 0.87), neither did the comparison of both groups to the surgeons (g = 1.23 and 0.51, respectively).

The correlation coefficient r was 0.68 ($p < 0.01$), which indicates a moderately positive correlation between suturing time and LS-CAT score (Fig. 4a). The ICC value was 0.826, which indicates good inter-rater reliability.

4. Discussion

The influence of practice schedule in motor skill learning, e.g. serial practice or blocked practice, has been widely studied and applied in athletic training [9]. The concept had not been introduced into the era of laparoscopic skill learning until 2002 [10]. In FLS, the simulators, e.g. peg transferring, pattern cutting, endoloop, and intracorporeal suture, were arranged in a block or random order, which has been shown to be equally effective in laparoscopic skill learning [11]. Except FLS, practice schedule was scarcely mentioned in the literature of laparoscopic skill training [10,12,13].

Laparoscopic suturing is a complicated procedure. Mackay et al. proposed that the more complex a task is, the more basic practice should take place [10]. Stepwise program is constructed based on blocked practice which is considered beneficial for motor skill acquisition [7]. We deconstructed laparoscopic suturing into five essential steps for practice in each block. The difference between our stepwise program and FLS is that each block in FLS is an independent task, whereas in our stepwise program, the step in the previous block is sequentially linked to the one in the next block. Two participants shared one set of instruments, and alternated between practice and rest/observation. It is believed that the discussion generated between the participants will strengthen the technique. The intentional break interspersed between in laparoscopic training has been shown to improve skill acquisition [10,12].

The learning outcome of stepwise program was promising. Comprehensive improvement was observed in the overall suturing time, the overall LS-CAT score, and the score in each domain. The simultaneous decline of suturing time and LS-CAT score is a definitive indicator of performance boost. It is evident that stepwise program is effective in skill acquisition of laparoscopic suturing for trainees and medical students.

All the medical students were naïve to laparoscopic suturing. A tutorial video of laparoscopic suturing was provided prior to the course to help them understand and improve skill acquisition [14]. All the trainees had undergone laparoscopic suturing training; therefore, the pre-course video was not provided.

It was beyond our expectation that it merely took 4 h of the practice for the medical students to obtain the skill of laparoscopic suturing. The task could be accomplished by the medical students within the median time of 5 min after the first course, and 3.5 min

Table 1
Suturing time and LS-CAT scores.

	Test	Overall (n = 18)	Students (n = 10)	Trainees (n = 8)	Surgeons (n = 6)
Time (Sec.)	1st	245 (202–428)	289 (202–411)	227 (194–524)	140 (83–169)
	2nd	203 (164–268)	202 (188–238)	234 (149–304)	
	p	<0.01	0.07	0.04	
Total score	1st	21.3 (18.0–23.5)	22.0 (19.5–23.5)	19.8 (16.5–25.5)	11.3 (9.5–15.0)
	2nd	16.8 (14.0–20.0)	19.0 (15.0–21.0)	15.8 (13.3–17.0)	
	p	<0.01	0.03	0.02	
Pick up needle	1st	4.8 (3.0–7.0)	5.3 (3.0–7.0)	4.3 (2.3–6.5)	2.8 (2.0–4.0)
	2nd	3.5 (2.5–5.0)	4.0 (2.5–5.5)	3.5 (2.3–4.0)	
	p	0.03	0.15	0.07	
Pass needle through edges	1st	4.5 (4.0–5.0)	4.8 (4.5–5.5)	4.3 (3.5–5.0)	2.5 (2.0–4.0)
	2nd	3.5 (2.5–4.5)	4.3 (2.5–5.5)	3.3 (2.3–3.5)	
	p	<0.01	0.12	0.02	
Create first double wind	1st	5.0 (4.5–6.5)	5.0 (4.0–5.5)	5.8 (4.5–6.8)	2.8 (2.0–3.5)
	2nd	4.5 (3.5–5.0)	5.0 (3.5–5.5)	4.0 (3.3–4.5)	
	p	0.048	0.58	0.03	
Knot tying	1st	6.0 (5.5–7.0)	6.0 (5.5–6.5)	6.0 (5.3–7.3)	3.3 (2.5–4.5)
	2nd	5.0 (4.5–6.0)	5.0 (4.5–6.0)	4.8 (3.8–5.8)	
	p	0.02	0.21	0.06	

The values are stated in median (interquartile range, IQR). The statistics is made by Wilcoxon test.

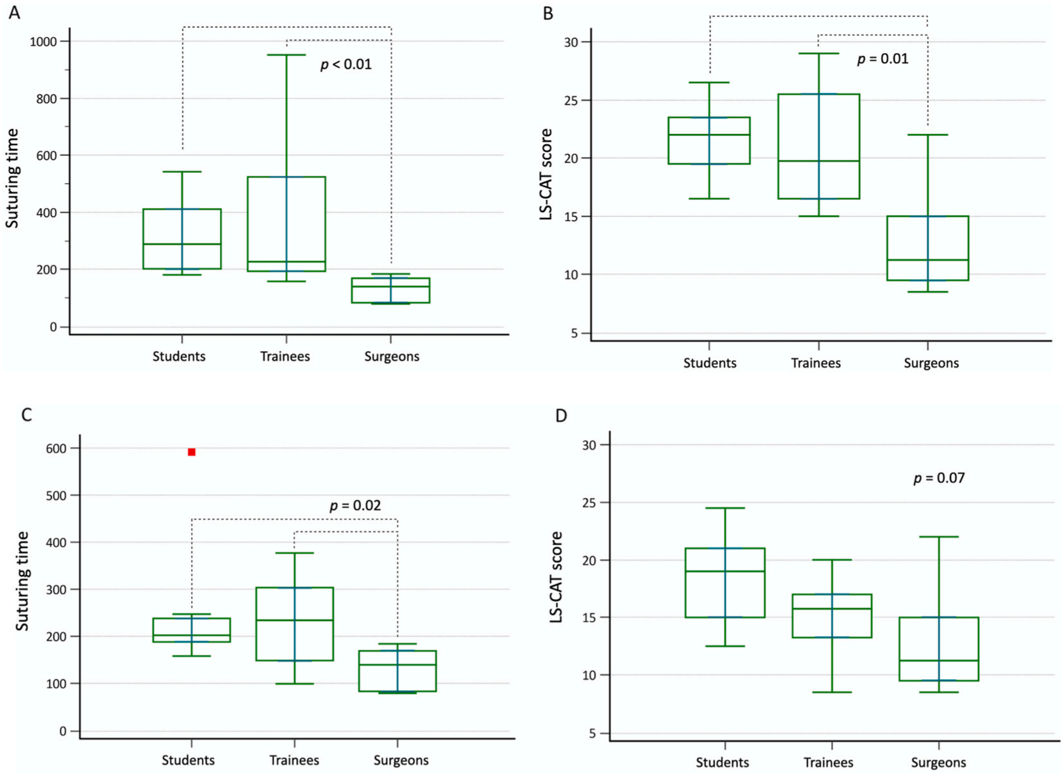


Fig. 3. Cross-group comparison of the 1st test (a &b) and the 2nd test (c & d).

after the second course. The difference of the suturing times between 1st and 2nd tests was borderline insignificant, which might be because of hitting the plateau and the small number of the participants. In addition to effectiveness, stepwise program demonstrates great learning efficiency for novices.

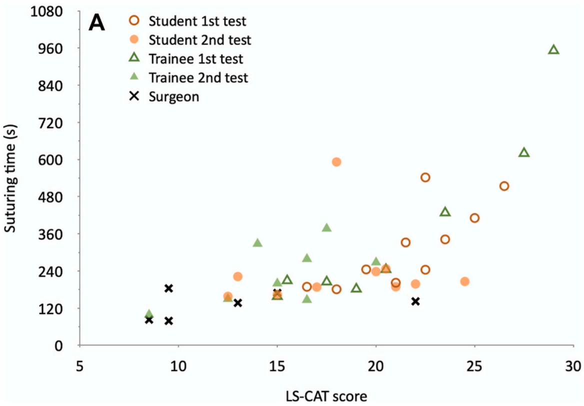
It was suggested that beginners should undergo basic laparoscopic skill training prior to suturing [2]. However, a catch-up phenomenon was noted in another study that junior trainees with minimal laparoscopic experiences would have comparable competency to senior ones after laparoscopic suturing training [15]. It was also noticed in our study. With one course of stepwise training, the students have the competing performance to the trainees in terms of both suturing time and LS-CAT score; after the second course, the performance of the students and trainees remained similar, and the LS-CAT score was even approaching to the surgeons'. Our results support that laparoscopic suturing training can be launched early, particularly for medical students to get prepared for the future clinical work in surgical department. Laparoscopic skill learning is not necessarily hierarchical.

Time was the main measurement for performance, however, being criticized by its insufficient sensitivity [5,16]. Therefore, assessment tools were developed [8,14–16]. The association between performance time and scores has not been investigated in the literature. A positive correlation between time and LS-CAT score was noted from out data. The plot distribution based on time and LS-CAT score was a biphasic curve (Fig. 4b). The initial trend of this curve (the solid arrow) showed that suturing time dropped rapidly; in the later phase (the dotted arrow), suturing time hits a plateau with minor improvement, nevertheless, the score continues to decline. Although the cutoff point was not statistically analyzed, 5 min of suturing time might serve as the milestone to enter the next phase from the initial phase. In this study, all attending surgeons fulfilled the task within 3 min.

Identifying a participant's location on the learning curve is beneficial to give a customized recommendation [17]. The majority of learning curves were constructed by time [18] or performance scores [2]. The plot distribution can provide the insight of learning phases. When hitting the milestone of 5 min, it may indicate that participants have obtained initial proficiency. From the perspective of an instructor, the advice should be given to focus on the detail of the operation to improve precision and accuracy rather than on merely pursuing the speed.

Reliability is the indicator of consistence and stability for performance measurement. ICC is the statistical tool used in the literature, also in this study, to evaluate reliability [3,19]. The assessment model of single measurement by multiple raters was frequently used in the literature. Our previous research demonstrated that this model was highly reliable [20]. In this study, we followed the same assessment model. A good inter-rater reliability was similarly noticed.

The small sample size and size discrepancy of each group were noted. The enrollment of the trainees and attending surgeons was hampered by the clinical workloads of both the instructors and participants. It also led to the heterogeneity and the vastly diverse results of the trainees. Nonparametric statistical methods were used for the small number of the sample and the non-normally distributed data.



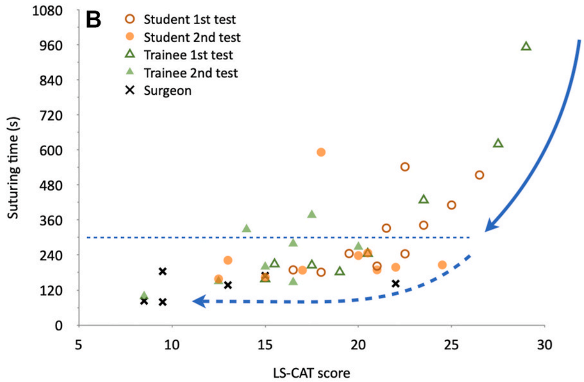


Fig. 4. Plot distribution based on suturing time and LS-CAT score. (a) plain graph. (b) with trending marks.

We acknowledge several limitations. As mentioned earlier, those include the size discrepancy between the groups, the heterogeneity of the trainees and the small sample size. The data is not sufficient to differentiate the learning outcomes between different levels of trainees. The small sample size might magnify the type II error and diminish the power of the statistical results, therefore, we conducted Hedges' g to evaluate the practice significance of the comparison. The pre-course skill level of the medical students was unknown for not setting up a test before the 1st course. This study also lacks of a control group who receives ordinary laparoscopic suturing practice. It should be the next imperative subject that we need to work on.

5. Conclusions

The results of this study suggest that stepwise training program is effective and efficient in improving laparoscopic suturing for medical students and surgical trainees. With stepwise training, medical student could learn laparoscopic suturing efficiently and catch up the level of surgical trainees. For the participants who have obtained initial proficiency in laparoscopic suturing, the advice should be given to focus on the detail of the operation rather than the speed. Further study is mandatory to compare stepwise training with the ordinary practice of laparoscopic suturing.

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Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Hsin-An Chen: Writing – original draft, Data curation, Conceptualization. **Shih-Wei Huang:** Resources, Formal analysis, Conceptualization. **Shih-Chiang Shen:** Visualization, Software, Data curation. **Kuei-Yen Tsai:** Writing – review & editing, Project administration, Formal analysis. **Hsin-Hong Kuo:** Writing – review & editing. **Bernard Dallemagne:** Writing – review & editing, Supervision. **Howard C. Jen:** Writing – review & editing. **Chin-Hung Wei:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

Drs. Shih-Chiang Shen, Kuei-Yen Tsai, Bernard Dallemagne and Howard C. Jen have no conflicts of interest and financial ties to disclose. Drs. Hsin-An Chen, Hsin-Hong Kuo and Chin-Hung Wei are the speakers in IRCAD-Taiwan. Dr. Shih-Wei Huang is the director of IRCAD-Taiwan.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e22563.

Appendices.

Laparoscopic suturing competency assessment tool.

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