The simulation training program of laparoscopic enteroenteric anastomosis on a 3D-printed model and the effect of left-hand dexterity training on this training

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Research Article

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Abstract

**Background** In surgery, most right-handed people don't have enough left-hand dexterity. We would like to utilize a convenient way to improve left-hand dexterity and study whether it could enhance the effectiveness of surgical training.

**Methods** Four residents were randomly divided into two groups. The subjects in the study group were required to use the left-hand computer mouse for 15 minutes every day for 30 days. The hand dexterity of all subjects was tested through the O’Conner Tweezer Dexterity Test and their performance of enteroenteric anastomosis on a specific 3D printed model was recorded and evaluated by Objective Structured Assessment of Technical Skill and Specific Rating Scales every time they train.

**Results** The average time for the left-handed test in the experimental group and control group was from 518.5s to 343s and from 531s to 444.5s respectively. There was a statistically significant difference in left-hand dexterity between the two groups (P=0.015).

The average performance score of the experimental group and control group improved from 25.5 to 42 and from 24.5 to 31.5 respectively. There was a statistically significant difference in training performance between the two groups in the 4th (P=0.014) and 5th (P=0.008) tests.

A figure about left-hand dexterity score and operation performance scores (Learning curve) was made. A table and a figure about the operation details in training were made.

**Conclusion** Regular surgical training on 3D printed models can improve suture performance while improving left-hand dexterity with a left-handed mouse can speed up the process and shorten the learning curve.

Introduction

Compared to the 88–92% of right-handed (RH) people worldwide, left-handed (LH) people make up a sizeable minority in the medical profession.[1] In orthopedics surgery, surgeons may use each hand differently or adjust their body positions to accommodate their hand dominance, depending on the side of the body being operated on.[2] Due to the limited operating room space, the assistant and the chief surgeon may run into each other during the procedure, which will interfere with a precise and painless procedure. This may be lessened if the non-dominant hand can be trained to have similar dexterity to the dominant hand. In a study about neurosurgery, many operations that require the dexterity of both hands were listed as clipping aneurysms, drilling and craniotomy, and tying knots. They found that the combination of both hands being trained to use all instruments well has a super-additive effect on operative technique.[3] Even though most surgical tools can be used with either the left or right hand, if the non-dominant hand is used skillfully, the overall result might be superior to using the dominant hand alone. One of the most fundamental surgical procedures, suturing, calls for the simultaneous use of both hands to operate the instrument. Suturing requires the use of both hands. Hold the needle in your right
hand and thread it into the tissue with your left hand. Use the left hand to hold the tweezers, the needle, and the thread in the middle, and then use both hands to tie the knot. The flexibility of both hands is required for this in a few specific ways. Poor suturing results, prolonged suturing times, or even poor incision matching and increased postoperative complications can result from insufficient flexibility in either hand.

Left-handed trainees were significantly more likely than right-handed trainees to report operating with both hands equally or with the non-dominant hand.[4] Left-handed operators felt their hands were more flexible when sewing than right-handed operators.[2] So we decided to test and train the dexterity of the left hand of right-handers.

In surgical operations, open surgery, laparoscopic surgery, and robotic surgery all need to use sutures. Studies have shown that robotic surgery can eliminate the difference between the left and right hands. However, there are still differences between the left and right hands in laparoscopic and open surgery.[5] However, in surgical operations, open and laparoscopic surgery are more commonly used by surgeons than robotic surgery. Especially under laparoscopy, the magnification of the field of view requires more delicate operations, such as cutting, hemostasis, and suturing. The ability to be facile with both hands is crucial for laparoscopic surgery.[6] Studies have shown that through regular left-handed mouse training with the non-dominant hand, the movement's bilateral transfer effect can improve the dominant hand's dexterity and enable the non-dominant hand to achieve similar dexterity to that of the dominant hand using a mouse.[7] Therefore, we trained the subjects with a left-handed mouse for 30 days. Before, during, and after the training, we conducted a two-hand flexibility test and a suture test in a validated 3D printed model to draw a learning curve to explore whether the training of the non-dominant hand can improve the performance of the suture in the surgery.

**Methods**

We recruited four residents from Zhejiang Provincial People's Hospital, which were all PGY-1. We looked into some of their essential characteristics to ensure they were all right-hand dominant, had no laparoscopic procedures experience, left-handed training experience, 3D printing models, and Ex-Vitro animal and live animal experience. They were randomly divided into two groups of 2 people each.

The two groups of subjects were asked to complete the laparoscopic side-to-side enteroenteric anastomosis in a validated 3D printed model (Fig. 1). We did the following to ensure that the training was standardized: 1. Pre-marked spots were placed at the entry and exit points to ensure the task was standardized for exiting through the incision before taking the second bite. 2. Participants will be asked to perform each step with specified hands and instruments. At least two experts have validated these steps before the training takes place. [8] Every subject was evaluated by the Objective Structured Assessment of Technical Skill (OSATS) (Table 1) and the Specific Rating Scales (SRS) (Table 2) by at least two experts with extensive experience in general surgery.[9–11] The evaluator does not know the subject of the evaluation and the number of training sessions.
All subjects were tested in a quiet, comfortable, well-lit room to avoid distractions. Before each test, a teacher read each participant's exact and clear instructions from written notes. Subjects completed the O’Conner Tweezer Dexterity Test, a validated dexterity test[12] according to the instructions (Fig. 2). Time to completion was measured in seconds, beginning when the participant picked up the tweezers and ending when the participant put down the tweezers after filling the board. Their time to complete the test will be recorded and scored according to a standardized scale.[1]

The experimental group was equipped with the left-handed computer mouse, a multifunctional wireless trackball mouse (Fig. 3). They were required to use the mouse for 15 minutes daily to browse pages, edit text, play computer games, etc., for 30 days. The control group of participants did not use the left-handed computer mouse.

All subjects were asked to complete the O’Conner Tweezer Dexterity Test and enteroenteric anastomosis every seven days. Their test score and performance in operation were recorded until they met the last test on the 30th day.

After the 30-day training, the two groups of subjects were asked to complete the laparoscopic enteroenteric anastomosis in the 3D-printed model again. Then every subject was handed global rating scales (OSATS) and specific rating scales (SRS) to re-evaluate their performance.
Table 1
The Objective Structured Assessment of Technical Skill (OSATS)

<table>
<thead>
<tr>
<th>OSATS</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Respect for tissue</td>
<td>Frequently used unnecessary force on tissue or caused damage by inappropriate use of instruments.</td>
</tr>
<tr>
<td>Time and motion</td>
<td>Many unnecessary moves</td>
</tr>
<tr>
<td>Instrument handling</td>
<td>Repeatedly makes tentative or awkward moves with instruments.</td>
</tr>
<tr>
<td>The flow of operation and forward planning</td>
<td>Frequently stopped operating and seemed unsure of the next move.</td>
</tr>
<tr>
<td>Knowledge of specific procedures</td>
<td>Deficient knowledge. Needed specific instruction at most operative steps</td>
</tr>
</tbody>
</table>
Table 2  
The Specific rating scale (SRS)

<table>
<thead>
<tr>
<th>Specific rating scale</th>
<th>Score</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needles handling</td>
<td>Deficient needle handling; takes longer than expected and does not position correctly.</td>
<td>Optimal needle handling; manages to position correctly but sometimes takes longer than expected.</td>
<td>Consistently handles the needle correctly.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tissue exposure using a non-dominating hand.</td>
<td>Does not use/partially use non-dominating hand</td>
<td>Always uses a non-dominating hand but does not expose tissues correctly.</td>
<td>Always uses a non-dominating hand, exposing tissues correctly without harming them.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knot-tying</td>
<td>Does not know how to tie knots/ incomplete knot-tying</td>
<td>Completes knot-tying but sometimes hesitates or makes clumsy movements.</td>
<td>Completes knot-tying with fluidity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final product quality</td>
<td>Completes the exercise partially; suture does not affront structures.</td>
<td>Completes the exercise affronting structures yet does not achieve symmetry regarding borders or distance between stitches.</td>
<td>Completes the exercise affronting structures correctly with symmetric and equidistant stitches</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results

Statistics analysis

In this study, t-test and Pearson correlation analysis was used in parametric test. No non-parametric test was used in this study. SPSS 25.0.0 and Microsoft office Excel 2021 were used for statistical analysis and figure plotting. P < 0.05 was considered statistically significant.

Hand dexterity test and performance scores

The average time for the left-handed test in the experimental group improved from 518.5 seconds initially to 343 seconds in the last test. The average time of the right-hand test for the experimental group improved from 423.5 seconds initially to 280 seconds in the last test.

The average left-handed test time for the control group improved from 531 seconds initially to 444.5 seconds on the last test. The average right-hand test time for the control group improved from 437.5 seconds initially to 293.5 seconds on the last test. (Fig. 4) A statistically significant difference in left-hand
dexterity between the two groups could be found in the 5th test, which could be found in Table 3. (P = 0.015)

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>The experimental group LH</td>
<td>1</td>
<td>513</td>
<td>518</td>
<td>405</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>524</td>
<td>504</td>
<td>452</td>
<td>385</td>
</tr>
<tr>
<td>The control group LH</td>
<td>1</td>
<td>534</td>
<td>477</td>
<td>426</td>
<td>448</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>528</td>
<td>500</td>
<td>442</td>
<td>430</td>
</tr>
<tr>
<td>P-value</td>
<td>0.184</td>
<td>0.237</td>
<td>0.845</td>
<td>0.181</td>
<td>0.015</td>
</tr>
</tbody>
</table>

LH: left-hand. P < 0.05 was considered statistically significant.

The experimental group's average performance score (OSATS + SRS) improved from 25.5 initially to 42 on the last test. The average performance score for the control group improved from 24.5 seconds initially to 31.5 on the last test. (Fig. 5) A statistically significant difference in training performance between the two groups could be found in the 4th (P = 0.014) and 5th (P = 0.008) tests, which could be found in Table 4.

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>The experimental group</td>
<td>1</td>
<td>26</td>
<td>31</td>
<td>28</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>25</td>
<td>30</td>
<td>33</td>
<td>40</td>
</tr>
<tr>
<td>The control group</td>
<td>1</td>
<td>25</td>
<td>31</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>24</td>
<td>30</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>P-value</td>
<td>0.293</td>
<td>1.000</td>
<td>0.237</td>
<td>0.014</td>
<td>0.008</td>
</tr>
</tbody>
</table>

P < 0.05 was considered statistically significant.

Statistical tests revealed that there was a statistically significant correlation between number and dexterity (r = 0.942, P < 0.001), number and score (r = 0.926, P < 0.001), and dexterity and score (r = 0.884, P = 0.001) in the experimental group. In the control group, although there was a statistically significant correlation between number and flexibility (r = 0.825, P = 0.003), there was no statistically significant correlation between number and score and flexibility and score (r = 0.825, P = 0.003, r = 0.825, P = 0.003, respectively)
The time spent using the left hand was converted into a score based on the reference table in the tester's manual of the O’Conner Tweezer Dexterity Test, with higher scores representing greater dexterity. (Table 5) The converted scores of the two groups and the summed OSATS and SRS scores were shown in Fig. 6.

Table 5
Standard Norms for the O’Connor Tweezer Dexterity Test (part)

<table>
<thead>
<tr>
<th>Time used(s)</th>
<th>Standard Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>7.5</td>
</tr>
<tr>
<td>271</td>
<td>7</td>
</tr>
<tr>
<td>289</td>
<td>6.5</td>
</tr>
<tr>
<td>309</td>
<td>6</td>
</tr>
<tr>
<td>333</td>
<td>5.5</td>
</tr>
<tr>
<td>360</td>
<td>5</td>
</tr>
<tr>
<td>393</td>
<td>4.5</td>
</tr>
<tr>
<td>432</td>
<td>4</td>
</tr>
<tr>
<td>479</td>
<td>3.5</td>
</tr>
<tr>
<td>539</td>
<td>3</td>
</tr>
<tr>
<td>615</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Operation details collection:

We counted the subjects' surgical performance in terms of several key steps. Collation of sutures and two-handed instrumentation to adjust suture position were defined as negative indicators. The left-handed use of laparoscopic surgical forceps to hold tissue and left-handed use of laparoscopic surgical forceps with suture penetration was defined as positive indicators. The specific definitions were as follows:

1. **Adjusting the stitching**: Adjustment of messy stitch lines for a smooth next suture. One-time successful completion of an operation will not be recorded, and multiple operations will be recorded.

2. **Adjustment of the needle position with two-handed instruments**: After each thread, the needle is often placed in a position where it cannot be adjusted to the next suture at one time due to the length of the suture, and the need for multiple operations to adjust the needle position will be recorded.

3. **Tissue clamping with laparoscopic forceps in the left hand**: Tissue was clamped with laparoscopic forceps in the left hand to facilitate exposure of the incoming and outgoing needle views, and the
total number of times was determined because each step was standardized. Inadequate exposure was defined as the inability to hold the tissue in a single pass, the inability to successfully complete the needle penetration, or the inability to see the needle in its entirety after holding the tissue.

4. **Using the left hand to use laparoscopic forceps to go out with the suture needle:** The subject will be asked to use the left hand to use the laparoscopic forceps to pinch the suture needle out. Since each operation step is standardized, the total number of times is determined. Removing the needle with the right-handed needle holder or not being able to complete the operation in one go and requiring multiple completions will be recorded.

The operation details collection was summarized in Table 6, and the trend line was shown in Fig. 7.

![Table 6: Operation details collection](image)

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of times</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>The experimental group</td>
<td>Adjusting the stitching</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Adjustment of the needle position</td>
<td>10</td>
<td>5</td>
<td>8</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Tissue clamping</td>
<td>20/27</td>
<td>20/27</td>
<td>20/27</td>
<td>24/27</td>
<td>26/27</td>
</tr>
<tr>
<td></td>
<td>Needle pulling out</td>
<td>18/27</td>
<td>21/27</td>
<td>25/27</td>
<td>24/27</td>
<td>26/27</td>
</tr>
<tr>
<td></td>
<td>Time(min)</td>
<td>50</td>
<td>38</td>
<td>42</td>
<td>37</td>
<td>30</td>
</tr>
<tr>
<td>The control group</td>
<td>Adjusting the stitching</td>
<td>14</td>
<td>10</td>
<td>4</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Adjustment of the needle position</td>
<td>21</td>
<td>12</td>
<td>8</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Tissue clamping</td>
<td>22/27</td>
<td>22/27</td>
<td>23/27</td>
<td>19/27</td>
<td>22/27</td>
</tr>
<tr>
<td></td>
<td>Needle pulling out</td>
<td>22/27</td>
<td>23/27</td>
<td>20/27</td>
<td>21/27</td>
<td>22/27</td>
</tr>
<tr>
<td></td>
<td>Time(min)</td>
<td>60</td>
<td>45</td>
<td>42</td>
<td>35</td>
<td>33</td>
</tr>
</tbody>
</table>

**Discussion**

This study found that non-left-handed people can significantly increase their left-handed dexterity by practicing with a left-handed mouse for at least 15 minutes daily. Members of both groups improved during the surgical suture training, which was conducted every seven days, as evidenced by raised OSATS and SRS scores. The learning curve shows that after left-hand training, members of the experimental group improved more than those in the control group in specific surgical procedures, such as the OSATS and SRS scores. However, there was no significant variability in the improvement of the procedure time between the two groups, probably because both groups had an increasingly full understanding of the procedure. In contrast, the variability in the performance of the surgical scores between the two groups
could more likely stem from the increased performance of the surgical operations, which the practice of dexterity may improve.

Simple models, cadaver models (pigs), and other techniques frequently used in surgical training have been around for a while, but the emergence of 3D printed models has altered the traditional pattern. [13] High-quality 3D-printed surgical models may be crucial for teaching and assessing procedures. Instead of operating on a simple suture model, the 3D printed model used in our experiments is a tried-and-true model with texture and tension close to those of actual tissue. As a result, it can realistically simulate the situation in the surgical scene, from simple to complex sutures[14]. Future research in realistic surgical scenarios can confirm the claim that left-hand training can improve intraoperative performance.

In the laparoscopic environment, completing the entire tissue suture is not only simple knotting but also requires operations such as threading the needle, exiting the needle, straightening the thread, and adjusting the direction of the needle. In addition, clamping the tissue also requires left-handed instrumentation, and these actions account for a high percentage of the actual surgery. A high degree of left-handed dexterity will help to complete these actions smoothly, saving the overall operation time and improving the overall surgical outcome. In our experiment, we standardized each step of the procedure and required each trainer to use the left hand to complete the tissue clamping and the needle discharge so that the success rate of a left-handed instrument could be counted. We were surprised to see that the percentage of operations performed with the left hand increased with practice, and we also found that the overall procedure scores increased.

In terms of suture, in recent years, many researchers have explored whether global scales and checklists can accurately reflect the level of respondents [9, 15, 16] and proposed and developed some new evaluation tools and scales. [17] For the discussion of OSATS, the scale can comprehensively evaluate the overall performance level of surgery. Still, for evaluating a specific operation, some items in the scale will not be able to distinguish the level due to the experimental settings. To eliminate the influence of procedures other than suturing, a skilled surgeon will instruct the subjects in the general procedure of enteroenteric anastomosis on the model. The OSATS scale reflects the impact of this setting. Nearly all of the subjects on the test, as mentioned above, received 4–5 points for their understanding of specific procedures and the flow of operations. The SRS scale, which only evaluates sutures, and the assessment of the non-dominant hand, which can evaluate the subject's suture performance well, are also used to reflect changes in the level of suture technique among all participants.

Around the world, there are numerous instruments and tests for measuring finger dexterity. [12, 18] Most testing equipment is used to assess the rehabilitation of manual dexterity in patients with nerve injuries. Different testing modalities have advantages in different disciplines.[19, 20] The O’Conner Tweezer Dexterity Test is more frequently used to evaluate surgical abilities. [21, 22] This test calls for the use of tweezers, and tweezers and gripping instruments are essential tools for surgical operations which are close to the surgical scene. This could be the cause why we chose it. The results suggest that left-handed
mouse-trained participants scored higher on this test and performed better in surgical settings, indicating a possible link. In the future, more diverse surgical case studies may be investigated.

There are many ways to exercise and improve left-hand dexterity, but most of them are applied to the post-operative rehabilitation of patients with hand and nerve injuries. There are not many studies related to improving left-hand dexterity through daily training, and using a left-handed mouse may be one of the solutions methods. Although deliberate use of the left hand for daily activities is difficult for most people to accept because the initial experience of using it is very bad, after crossing a plateau period (7 days), the experience of using the mouse continues to increase as the dexterity improves. We were pleased to see that there were participants who were more willing to continue using the mouse through a small period of deliberate training, which may have contributed to both the improvement in left-hand dexterity and the improvement in surgical level.

**Strengths and limitations of this study:**

1. 3D printed small bowel model worthy of training for surgeons, especially novice residents
2. Not much research has been done on manual dexterity in surgery, and this experiment used a commonly used mouse for left hand dexterity training.
3. For the assessment of surgical quality, in addition to the use of globalized scales and specific assessment scales, we evaluated the trainees' performance through objective intraoperative operational indicators.
4. There are many methods about training hand dexterity, and this experiment chose the method of daily use of the mouse, but not systematic finger dexterity training.
5. Despite the rigorous selection of subjects, the enrollment of the group was low and it is hoped that the validity of the evidence will be strengthened by continuing to conduct more relevant studies to include more investigators

**Conclusion**

Regular surgical training on 3D printed models can improve suture performance, while improving left-hand dexterity with a left-handed mouse can speed up the process and shorten the learning curve.

**Declarations**

**Ethics approval and consent to participate** All methods were carried out in accordance with the Declaration of Helsinki and relevant guidelines. According to the notice on the issuance of ethical review measures for human life science and medical research issued by the National Health Commission of the People's Republic of China on February 18, 2023, Article 32 of Chapter 3 states that using human information data or biological samples to carry out human life science and medical research in the following situations does not cause harm to the human body, does not involve sensitive personal information or commercial interests, Ethical review can be exempted to reduce unnecessary burdens on
researchers and promote the development of life sciences and medical research involving humans. More ethical content can be found in http://www.nhc.gov.cn/qjjys/s7946/202302/c3374c180dc5489d85f95df5b46afaf5.shtml. This study only involves trainees, and the models used are all non-biological models that do not include any patients, animals, or other organisms. Therefore, it can be considered that there is no need for ethical review. All trainees have agreed and signed the informed consent form. They all acknowledge the risks involved and agree to use their training data for this research.

Consent for publication Not applicable.

Availability of data and materials All data analyzed during this study are included in the supplementary information files. The datasets of the training videos used and analyzed during the current study available from the corresponding author on reasonable request.

Competing interests Zhihao Zhu, Jinlei Mao, Hao Chen, Lidong Cao, Jianfu Xia, Jin Yang, and Zhifei Wang have no conflicts of interest or financial ties to disclose.

Funding There was no financial support for this study.

Author's contributions Prof. Zhifei Wang planned the research. Zhihao Zhu, Jinlei Mao, Hao Chen, and Lidong Cao conducted the research. Zhifei Wang, Jianfu Xia, and Jin Yang analyzed and evaluated the trainer videos. Zhihao Zhu wrote the manuscript and all authors reviewed the manuscript.

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References


Ahead of Print(5):e2686.


Figures
Figure 1

The three-dimensional printed intestinal anastomosis model under laparoscopic view
Figure 2

The O'Conner Tweezer Dexterity Test
Figure 3

The left-handed computer mouse
Figure 4
The Hand Flexibility Test

Figure 5
The training performance score
Figure 6

The LH dexterity score and operation performance scores (Learning curve), LH: left-hand
Figure 7

Operation details collection

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Traineeinformationandexperimentaldata.xlsx