Experimental study of microvascular anastomosis: Comparison of the conventional method, back wall technique, and untied stay suture method

Abstract

Background

Compared with the conventional microvascular anastomosis method, the back wall technique and untied stay suture method allow for better visualization of the vascular lumen and have been reported to be effective for beginner surgeons. However, there are no reports of such advantages from experimental studies. The present study compared the usefulness of the conventional method (Method C), back wall technique (Method B), and untied stay suture method (Method U) in rats.

Methods

Ninety end-to-end anastomosis procedures of the right femoral artery and vein were performed in rats. The anastomosis condition was assessed at the completion of suturing one side, at the completion of vascular anastomosis, and on postoperative day 7.

Results

After suturing one side, suture errors were observed in three veins with Method C. Immediately after the completion of vascular anastomosis, blood flow was impaired in one vein with Method C. On postoperative day 7, blood flow was impaired in one artery and one vein with Method C, one vein with Method B, and one artery with Method U.

Conclusions

No significant differences were observed between back wall technique and the untied stay suture method. However, the conventional method was more likely to lead to suture error or impaired blood flow compared with back wall technique and the untied stay suture method.

Key words: Microsurgery; Microvascular anastomosis; Vascular end-to-end anastomosis

Introduction

Microvascular anastomosis began in 1960 with the successful anastomosis of a 1.4-mm-diameter blood vessel under a surgical microscope by Jacobson and Suarez.[1] Currently in Japan, the typical microvascular anastomosis methods use two stay sutures, as described by Acland et al. (conventional method),[2-4] posterior wall first anastomotic technique (back wall technique),[5,6] or the untied stay suture method,[7,8] which was devised as a method to anastomose blood and lymphatic vessels that have external diameters of 0.3-0.5 mm or less.

The present study compared the usefulness of the conventional method (Method C), back wall technique (Method B), and untied stay suture method (Method U) as microvascular anastomosis methods in an experimental study involving rats.

Methods

The surgeons completed Microsurgery Stage 5, which is the final stage of a microsurgery training program[9] and had clinical microsurgery experience of 2 years (Surgeon A), 6 years (Surgeon B), and 20 years (Surgeon C). Based on the classifications reported by Tang and Gidding[10], Surgeon A is Level 2, Surgeon B is Level 3, and Surgeon C is Level 4. Forty-five Wistar rats (10-week-old male rats; 230-280 g) were used. Three-type mixed anesthesia[11] was used for anesthesia. Each surgeon performed vascular anastomosis using the conventional method (Figure 1), back wall technique (Figure 2), and untied stay suture method (Figure 3) in five animals per method, resulting in end-to-end anastomosis of the right femoral artery and vein in a total of 15 animals. Ninety end-to-end anastomoses of the right femoral artery and vein (external diameter of approximately 1.0 mm) were performed in a total of 45 animals by the three surgeons (Figure 4).

The time required for artery and vein anastomoses was measured, and the anastomosis condition at the completion of suturing one side, completion of vascular anastomoses, and on postoperative day 7 were assessed. This study protocol was approved by the Animal Care and Use Committee of the author’s institution (No. 16-068) and was conducted based on the institution’s Animal Experiment Policy.

For statistical analyses, Friedman’s test was used for the time required for vascular anastomosis, and Fisher’s exact test was used to compare suture error and impaired blood flow. $P<0.05$ was considered significant.

Results

There were no deaths caused by anesthesia or the surgical procedure, and no animals died during observation.

The mean durations of artery and vein anastomoses for Method C, Method B, and Method U were: 28 minutes 33 seconds, 30 minutes 8 seconds, and 29 minutes 9 seconds, respectively, for Surgeon A; 20 minutes 16 seconds, 20 minutes 46 seconds, and 21 minutes 12 seconds, respectively, for Surgeon B; and 22 minutes 47 seconds, 23 minutes 4 seconds, and 23 minutes 46 seconds, respectively, for Surgeon C.

Surgeon B was the fastest, and Surgeon A was the slowest for all methods when evaluating the mean duration of anastomosis for artery and vein by surgeon (Table 1).

For all surgeons, Method C was performed the fastest when evaluating the mean duration of anastomoses for artery and vein by method ($P=0.0094$ for Friedman’s test) (Table 1).

In the assessment of anastomosis condition of the 90 anastomoses, suture errors at three veins were observed with Method C at the completion of suturing one side. Immediately after completion of vascular anastomosis, impaired blood flow of one vein was observed with Method C. On postoperative day 7, impaired blood flow was observed at one artery and one vein with Method C, one vein with Method B, and one artery with Method U (Table 2).

Assessment of suture error and impaired blood flow by surgeon showed errors at two vein sutures for Surgeon A and one vein suture for Surgeon C after suturing one side. However, significant differences between surgeons were not observed at this time point with Fisher's exact test (Table 3).

At completion of anastomosis, impaired blood flow of one vein by Surgeon A was observed, but this was also not significantly different among the surgeons (Table 3).

On postoperative day 7, one artery with impaired blood flow was observed for Surgeons A and B and one vein with impaired blood flow was observed for Surgeons B and C, although there were no significant differences among the surgeons (Table 3).

Combined intraoperative assessment after suturing one side and at completion of anastomosis showed that, intraoperatively, none of the surgeons had suture error or impaired blood flow during artery anastomosis, and Surgeon A had three and Surgeon C had one suture error or impaired blood flow during vein anastomosis; however, there were no significant differences among the surgeons (Table 4).

Furthermore, the addition of postoperative day 7 data showed that suture errors and impaired blood flow were observed in one artery for Surgeon A, one artery for Surgeon B, three veins for Surgeon A, one vein for Surgeon B, and two veins for Surgeon C. However, there were no significant differences among the surgeons (Table 4).

Assessment of suture error and impaired blood flow by method showed errors of three vein sutures with Method C after suturing one side; however, significant differences were not observed among the methods (Table 5).

At the completion of anastomosis, blood flow was impaired at one vein anastomosis with Method C, but significant differences were not observed among the methods (Table 5).

On postoperative day 7, impaired blood flow was observed at one artery with Method C, one artery with Method U, one vein with Method C, and one vein with Method B; however, no significant differences were observed among the methods (Table 5).

Combined intraoperative assessment after suturing one side and at completion of anastomosis showed that suture error and impaired blood flow were not observed at artery anastomoses. However, suture error and impaired blood flow were observed at four vein anastomoses with Method C, a significant difference with Fisher's exact test (P-value=0.027; P-value=0.032 when artery and vein were combined). The results therefore showed that anastomosis error and blood flow impairment are more likely to occur with Method C than with Method B and Method U (Table 6).

Furthermore, results with the addition of postoperative day 7 data showed that there were suture errors or impaired blood flow of one artery with Method C and one artery with Method U, and five veins with Method C and one vein with Method B. This resulted in a significant difference in vein anastomosis among the methods with Fisher's test (P-value=0.035); the P-value was 0.045 when artery and vein were combined (Table 6). It was also shown that anastomosis error and blood flow impairment are more likely to occur with Method C compared with Method B and Method U, though with a lesser degree of significance.

Based on the above, with the assessment of anastomosis condition, there were no significant differences between Method B and Method U, but suture error and impaired blood flow were more likely to occur with Method C than with Method B and Method U.

Discussion

The characteristics of each anastomosis method are that, after placing two stay sutures with the conventional method,[2-4] a front wall suture and back wall suture are added (Figure 1). In Japan, the conventional method is the first basic microvascular anastomosis method that is learned by beginners. It is also taught first in our microsurgery training program, where pupils learn the basic operation of forceps, needle holder, and needles.[3,4,9)]

The back wall technique[5,6)] involves passing the first suture through the back wall and is a method of suturing from back to front in order (Figure 2). The characteristics of the back wall technique are that the lumen can be visualized easily because the sutures start from the back wall, and that it involves a smaller chance of accidentally hooking the needle on the contralateral wall. Moreover, it does not require rotation of the blood vessel during anastomosis. In clinical practice, because it is not necessary to rotate the blood vessel during the procedure, it is useful in vascular anastomosis where the field of view is deep and narrow.[6)]

The untied stay suture method[7,8)] involves passing through the first suture at a site that is easiest at the front wall and uses a clip for holding the stay suture instead of tying (Figure 3). The characteristics of the untied stay suture method are that the lumen can be easily visualized because the stay suture is left behind in the vascular lumen without tying, and that the blood vessel only needs to be rotated 90 degrees during anastomosis. Moreover, by applying tension on the first and second stay sutures without tying allows for an easier anastomosis maneuver of the dilated vascular lumen. In clinical practice, it has been reported to be useful for anastomosis of blood vessels and lymph vessels with external diameters of 0.3-0.5 mm or smaller.[7)]

Back wall technique and untied stay suture methods have been reported to be effective for beginners because the vascular lumen can be visualized well.[5,7)] However, this has not been reported from experimental studies.

In 2015, we started a Microsurgery Training Program (MTP). The MTP starts with anastomosis of artificial blood vessels in Stage 1 and concludes with supermicrosurgery in Stage 5. With the completion of Stage 4, surgeons are given the opportunity for the first time in clinical practice to perform microvascular anastomosis.[9)]

To match the surgical technique level of the participating surgeons, only those who have completed the Stage 5 supermicrosurgery training were included. The three surgeons had clinical microsurgery experience of 2 years, 6 years, and 20 years.

We had predicted that the surgeon with the longest clinical experience would require the shortest amount of time for anastomosis; however, the mean duration of anastomosis for arteries and veins for all methods was fastest by Surgeon B who had 6 years of clinical experience, followed by Surgeon C (20 years of clinical experience) and Surgeon A (2 years of clinical experience). This is perhaps because surgeons who have completed Stage 5 have their own consistent pace in the speed of vascular anastomosis, indicating that clinical microsurgery experience does not necessarily correlate with anastomosis duration for arteries and veins.

For all surgeons, the mean duration of vascular anastomosis by method was fastest for Method C, which is the first method to learn as the basics of microsurgery. The order from fastest to slowest was Method C, Method U, and Method B for Surgeon A, and Method C, Method B, and Method U for Surgeons B and C. Method B required a longer time than Method C, likely due to difficulties in suturing and tying procedures at the back wall.[5)] Moreover, the anastomosis duration is longer with Method U compared with Method C, likely because Method U involves additional steps compared with Method C, where the first and second stay sutures are held with a vascular clip rather than tying, and additional time is required to use them as traction thread.

There were no significant differences between surgeons at any assessment time point in suture errors and impaired blood flow. This is likely because, while there were differences in clinical experience (2 years, 6 years, and 20 years), the surgeons had acquired sufficient microvascular anastomosis skills through the microsurgery training program and completing Stage 5.

Assessment of suture error and impaired blood flow by method showed that these issues were more likely to occur with Method C compared with Method B and Method U. Suture error and impaired blood flow are less likely to occur with Method B and Method U than with Method C, because Method B involves suturing from the back wall and can attain satisfactory visualization of the vascular lumen.[5,6] Moreover, Method U involves pulling the first and second stay sutures also used in Method C without tying and proceeds with the vascular anastomosis procedure in a condition where the surgeon can easily confirm the vascular lumen.[7] These indicate that both methods ensure satisfactory visualization of the vascular lumen. Suture errors of three veins were observed with Method C after suturing one side (Table 2); however, in all cases, the needle was hooked to the contralateral wall adjacent to the stay suture. The possible reason for this is that, by tying the stay suture, the distance between the back wall and front wall had shortened.

When comparing the anastomosis method of end-to-end anastomosis, rather than combining intraoperative assessment (after suturing one side + at completion of anastomosis) with postoperative day 7 data, the intraoperative assessment (after suturing one side + at completion of anastomosis) alone showed greater significance (Table 4, Table 6). This is likely because postoperative resting cannot be maintained in rats, resulting in thrombus formation at the anastomosis site, thereby affecting the assessment on postoperative day 7.

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Disclosure of conflict of interest

The author has no conflict of interest to disclose in relation to this study.

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Tables

Table 1. Mean Duration of Vascular Anastomosis by Surgeon

	Method C	Method B	Method U
Surgeon A	28 min 33 sec	30 min 08 sec	29 min 09 sec
Surgeon B	20 min 16 sec	20 min 46 sec	21 min 12 sec
Surgeon C	22 min 47 sec	23 min 04 sec	23 min 46 sec

Table 2. Suture Error and Impaired Blood Flow by Anastomosis Condition

After suturing one side

	Method C					Method B					Method U				
Surgeon A	A · V	A · ✖	A · V	A · ✖	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V
Surgeon B	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V
Surgeon C	A · ✖	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V

At completion of anastomosis

	Method C					Method B					Method U				
Surgeon A	A · V	A ·	A · ✖	A ·	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V
Surgeon B	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V
Surgeon C	A ·	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V

Postoperative day 7

	Method C					Method B					Method U				
Surgeon A	A · V	A ·	A ·	A ·	A · V	A · V	A · V	A · V	A · V	A · V	A · V	✖ · V	A · V	A · V	A · V
Surgeon B	✖ · ✖	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · V
Surgeon C	A ·	A · V	A · V	A · V	A · V	A · V	A · V	A · V	A · ✖	A · V	A · V	A · V	A · V	A · V	A · V

A: Artery V: Vein ✖ : Confirmed suture error or impaired blood flow

Table 3. Suture Error and Impaired Blood Flow by Surgeon (1)

After suturing one side

	Suture error and impaired blood flow	Surgeon A	Surgeon B	Surgeon C	P-value
Artery	−	15	15	15	1
	+	0	0	0	
Vein	−	13	15	14	0.762
	+	2	0	1	
Artery + Vein	−	28	30	29	0.77
	+	2	0	1	

At completion of anastomosis

	Suture error and impaired blood flow	Surgeon A	Surgeon B	Surgeon C	P-value
Artery	−	15	15	15	1
	+	0	0	0	
Vein	−	12	15	14	0.309
	+	1	0	0	
Artery + Vein	−	27	30	29	0.321
	+	1	0	0	

Postoperative day 7

	Suture error and impaired blood flow	Surgeon A	Surgeon B	Surgeon C	P-value
Artery	−	14	14	15	1
	+	1	1	0	
Vein	−	12	14	13	1
	+	0	1	1	
Artery + Vein	−	26	28	28	1
	+	1	2	1	

Table 4. Suture Error and Impaired Blood Flow by Surgeon (2)

After suturing one side + at completion of anastomosis

	Suture error and impaired blood flow	Surgeon A	Surgeon B	Surgeon C	P-value
Artery	−	15	15	15	1
	+	0	0	0	
Vein	−	12	15	14	0.302
	+	3	0	1	
Artery + Vein	−	27	30	29	0.318
	+	3	0	1	

After suturing one side + at completion of anastomosis + postoperative day 7

	Suture error and impaired blood flow	Surgeon A	Surgeon B	Surgeon C	P-value
Artery	−	14	14	15	1
	+	1	1	0	
Vein	−	12	14	13	0.857
	+	3	1	2	
Artery + Vein	−	26	28	28	0.722
	+	4	2	2	

Table 5. Suture Error and Impaired Blood Flow by Method (1)

After suturing one side

	Suture error and impaired blood flow	Method C	Method B	Method U	P-value
Artery	−	15	15	15	1
	+	0	0	0	
Vein	−	12	15	15	0.099
	+	3	0	0	
Artery + Vein	−	27	30	30	0.103
	+	3	0	0	

At completion of anastomosis

	Suture error and impaired blood flow	Method C	Method B	Method U	P-value
Artery	−	15	15	15	1
	+	0	0	0	
Vein	−	11	15	15	0.28
	+	1	0	0	
Artery + Vein	−	26	30	30	0.31
	+	1	0	0	

Postoperative day 7

	Suture error and impaired blood flow	Method C	Method B	Method U	P-value
Artery	−	14	15	14	1
	+	1	0	1	
Vein	−	10	14	15	0.725
	+	1	1	0	
Artery + Vein	−	24	29	29	0.68
	+	2	1	1	

Table 6. Suture Error and Impaired Blood Flow by Method (2)

After suturing one side + at completion of anastomosis

	Suture error and impaired blood flow	Method C	Method B	Method U	P-value
Artery	−	15	15	15	1
	+	0	0	0	
Vein	−	11	15	15	0.027
	+	4	0	0	
Artery + Vein	−	26	30	30	0.032
	+	4	0	0	

After suturing one side + at completion of anastomosis + postoperative day 7

	Suture error and impaired blood flow	Method C	Method B	Method U	P-value
Artery	−	14	15	14	1
	+	1	0	1	
Vein	−	10	14	15	0.035
	+	5	1	0	
Artery + Vein	−	24	29	29	0.045
	+	6	1	1	

Figure legends

Figure 1. Conventional method

The first suture is passed through (a) and is tied as a stay suture (b), and the second stay suture on the contralateral side is tied (c). At this stage, three sutures are added to the front wall to conclude the front wall suture, and the blood vessel is rotated using the stay suture (d). Subsequently, the back wall is sutured, and the vascular anastomosis is completed.

Figure 2. Back wall technique

The first suture is passed through the back wall (a) and is tied together as a stay suture (b). Subsequently, suturing is continued from back to front in order (c). Completed suture of the back wall (d).Vascular anastomosis is completed after suturing the front wall.

Figure 3. Untied stay suture method

The first suture is passed through the front wall, wherever is easiest (a), and the stay suture is held with a clip without tying (b). Another stay suture is passed through the contralateral side and held with a clip without tying (c). At this stage, the front wall is sutured and rotated 90 degrees (d). Subsequently, the back wall is sutured, and vascular anastomosis is completed.

Figure 4. Femoral artery and vein of a rat

(a) Skin incision to the rat is shown, (b) Femoral artery (external diameter of approximately 1.0 mm) before anastomosis

Conventional Method

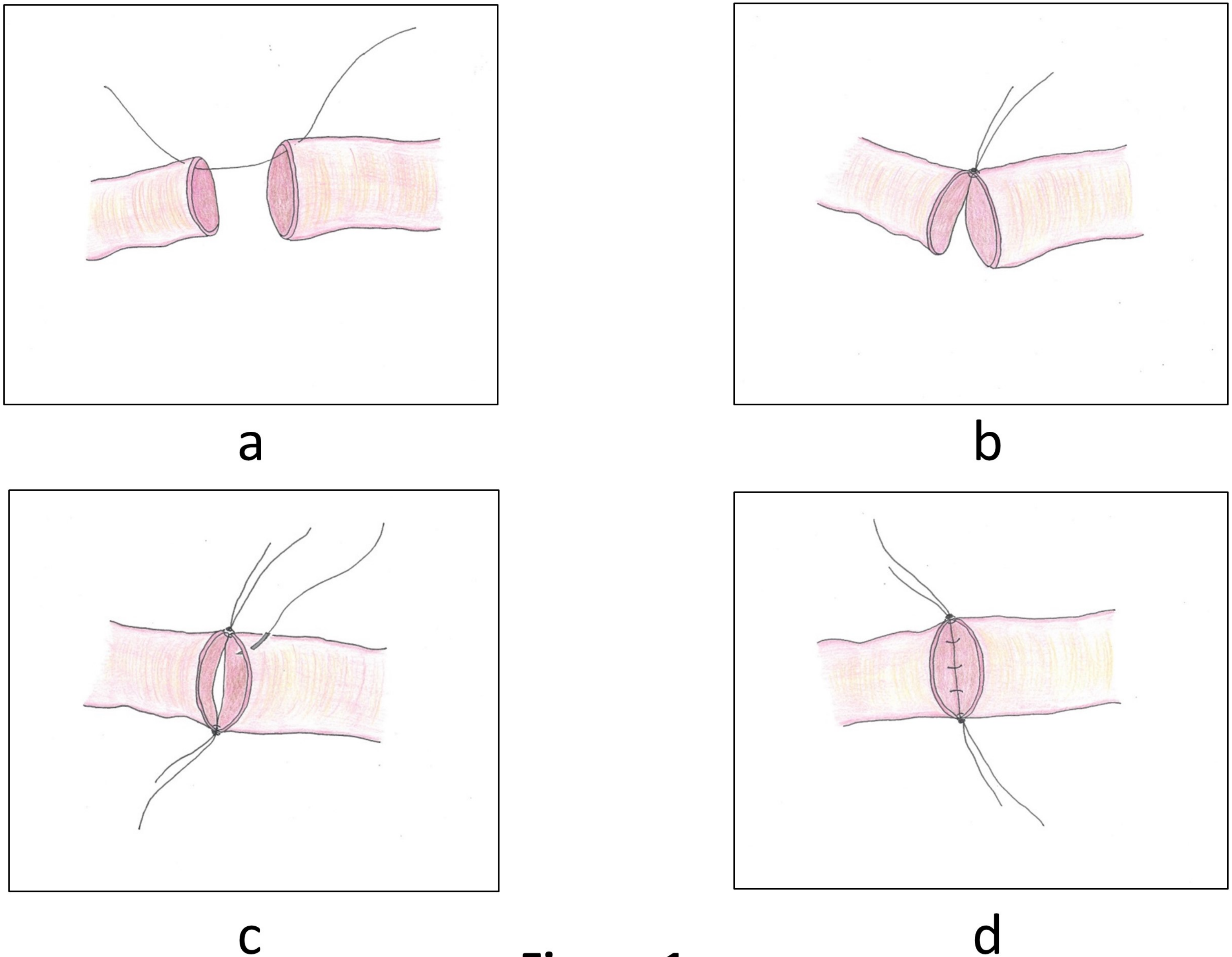


Figure 1

Back Wall Technique

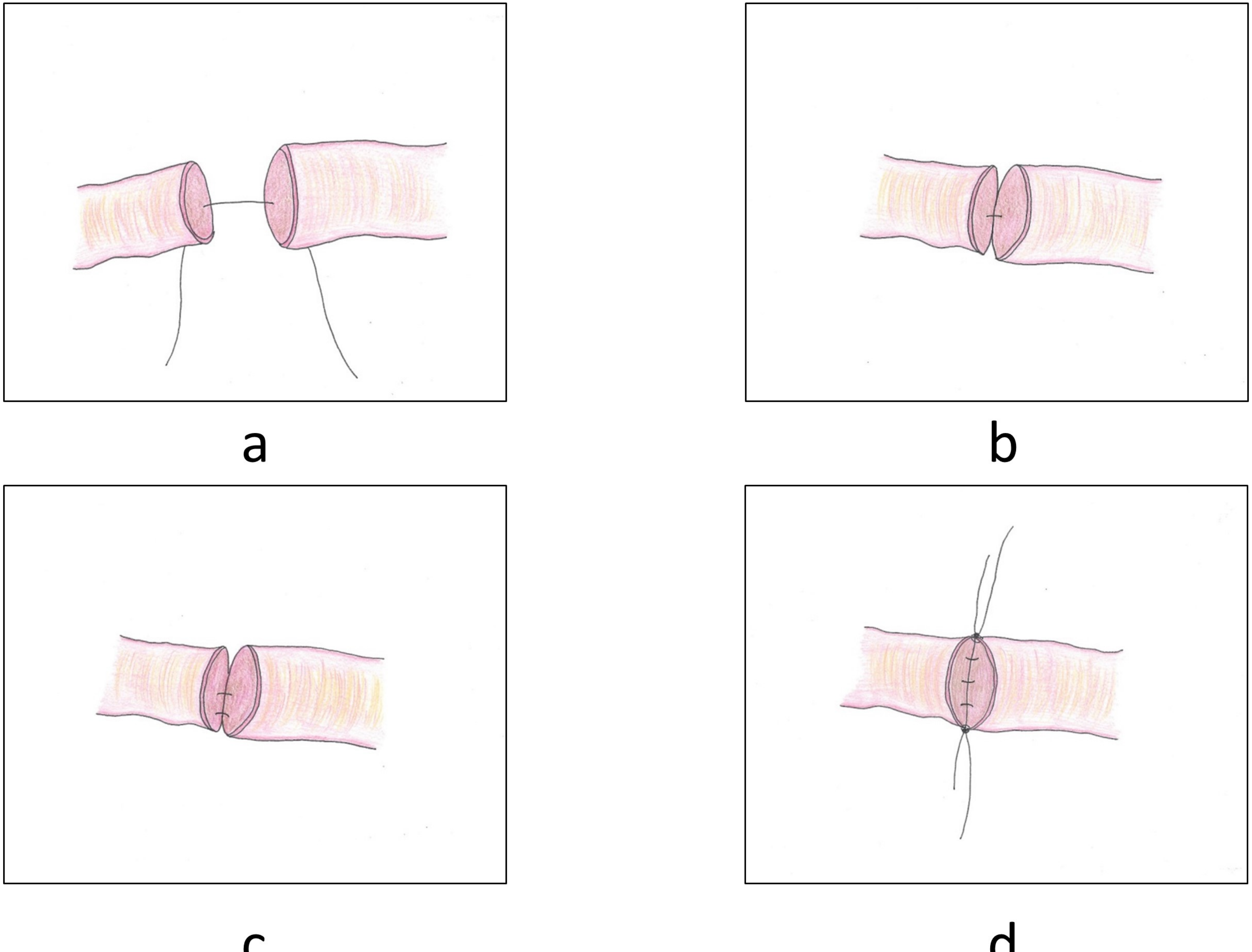


Figure 2

Untied Stay Suture Method

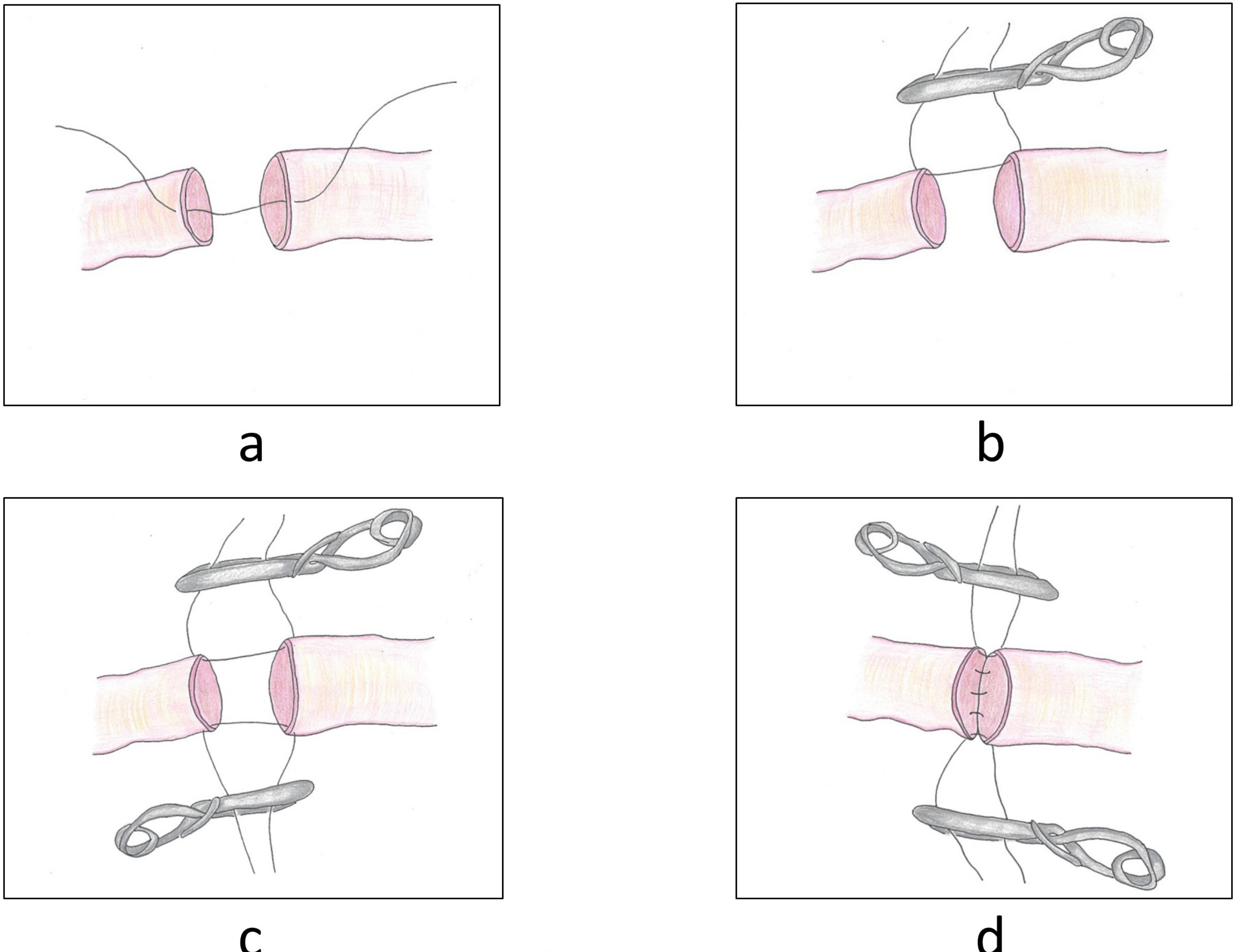
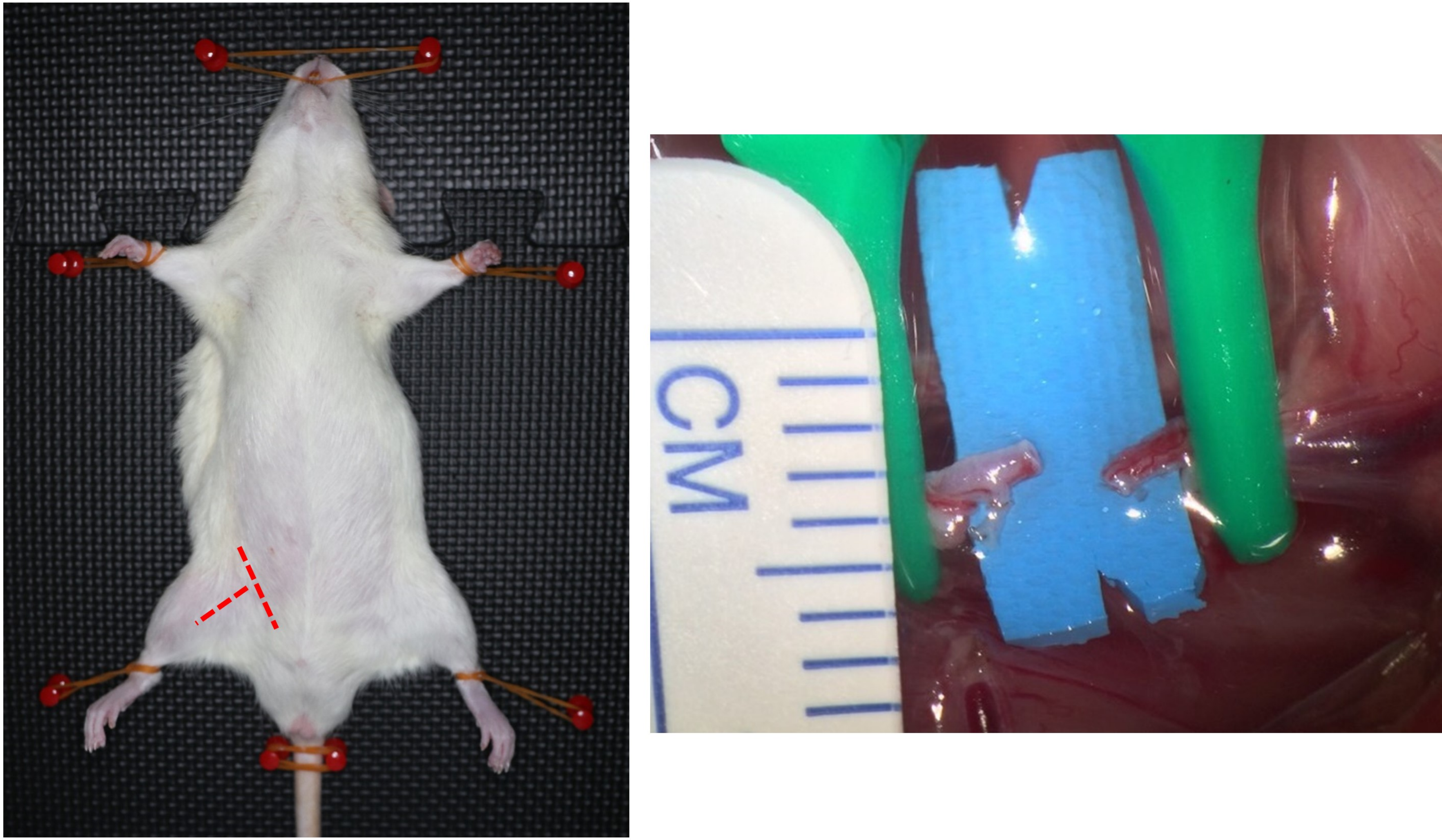


Figure 3



a b

Figure 4