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LARYNGOLOGY

Two-handed tying technique in vocal fold mucosa microsuture for the treatment of Reinke's edema

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Abstract

Background Removal of Reinke's edema may result in moderate to large-sized mucosal defect on the vocal fold, which heals by secondary intention. Microsuturing this defect may lead to primary wound healing with fastened recovery and less scar, but costs extra time and effort. Exploring methods that can shorten microsuture time is helpful for the wider application of this technology.

Study design Retrospective.

Methods 57 patients with Reinke's edema, who were admitted from November 2010 to June 2018, were enrolled as research subjects for the retrospective analysis. 27 patients were the knot pusher group (from November 2010 to March 2015), and 30 patients were the two-handed tying group (from April 2015 to June 2018). Evaluation indicators include the number of knots, the average time for suturing and tying the knot for each patient, and the occurrence of complications, subjective and objective voice assessments.

Results All patients underwent successful operation. The average time for making knots in the knot pusher group and two-handed tying group was 668.40 ± 173.73 s and 328.73 ± 121.0 s, respectively, and there was a statistically significant difference between the two groups ($p < 0.001$). No significant difference was noted in the mucosal avulsion, overall incidence of complications between the groups, and no significant difference was found between the two groups in terms of the preoperative and 3-month postoperative subjective and objective indicators.

Conclusion Microsuturing of Reinke's edema microflaps using the two-handed tying technique can achieve the similar effect with the knot pusher method, and save operation time while the surgeon is well trained.

Level of evidence 4.

Keywords Microsuture · Reinke's edema · Tying technique

Introduction

Reinke's edema of the vocal cord is a common voice disorder, and the lesion is located in the space underneath the epithelium of the vocal cord. It is characterized by fish belly-like swelling of the vocal cord, of which the surface is smooth and translucent, and its color is the same or similar to that of the vocal cord [1, 2]. The vocal cord sometimes may become relaxed and drooping under gravity and show weakness in closure [1]. Microscopic voice surgery is the primary measure for its treatment, with cold instrument and laser resection often used [3]. However, a large surgical defect could be left after the removal of the lesion, which may affect the repair process of surgical wounds, and tends to produce vocal cord scars, adversely affecting the patient's voice. Presently, it is suggested that, since Reinke's edema

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shows an excessive amount of mucosa, the tissue under the mucosa and some of the excessive amount of the mucosa should be removed, and then, a suitable mucosal flap should be made to cover it to eliminate the surgical wound of the vocal cord and reduce the formation of scar, steps that are beneficial to the recovery of the patient's voice.

The treatment methods of the mucosal flaps of Reinke's edema include direct coverage, bioadhesive bonding and microsuture, among which the microsuture method should be the most reliable [4–6]. Suturing of the vocal cord mucosa has a higher requirement for the microsurgical technique of the surgeon [4]. In clinical practice, the knotting method after suturing is mainly to make a knot outside the self-retaining laryngoscope, and then the thread knot is sent inside the self-retaining laryngoscope by the knot pusher all the way to the surface of the vocal cord mucosa [4]. However, this method has certain shortcomings. That is, when making a knot outside the self-retaining laryngoscope, the surgeon cannot observe the pulling situation of the vocal cord mucosa by the suture. Moreover, when the knot pusher pushes the thread knot, an excessively large tension may tear and rupture the mucosal flap. Since April 2015, we have attempted to use the two-handed tying technique inside the self-retaining laryngoscope. Herein, we compared the two-handed tying technique with the knot pusher method and report the findings.

Materials and methods

Research subjects

57 male patients with Reinke's edema, who were admitted from November 2010 to June 2018, were enrolled as research subjects for the retrospective analysis. During the same period, there were only five female patients with Reinke's edema who underwent surgery during the same period. To avoid the influence of female patients on objective voice assessment analysis, we excluded the female patients in this study. This research was approved by Ethics Committee of Sun Yat-Sen Memorial Hospital, Sun Yat-Sen University. The main manifestations were persistent or progressive hoarseness without dyspnea. They all had a long history of smoking and a history of excessive use of the throat. Laryngoscopic examination showed that they all had bilateral vocal cord lesions. Among them, 27 patients were subjected to a knot pusher to make knots (the knot pusher group) from November 2010 to March 2015, and they had an average age of 53.96 ± 6.08 years and a disease duration of 6 months to 10 years. According to Yonekawa classification [7], there were 11 cases of grade II (the anterior 2/3 of the bilateral vocal cords had contact) and 16 cases of grade III (full-length contact of the bilateral vocal cords). Thirty patients were subjected to the two-handed tying technique (the two-handed tying group) from April 2015 to June 2018, and they had an average age of 54.13 ± 6.71 years and a disease duration of 6 months to 12 years. According to Yonekawa classification, there were 17 cases of grade II and 13 cases of grade III.

Surgical equipment and instruments

OPMI® Vario/S88 microscope (Carl-Zeiss co., Oberkochen, Germany); CO2 laser (Lumenis AcuPulse 40 CO2 laser, wavelength 10.6 μm, Lumenis Ltd., Yokneam, Israel); 980 nm/1470 nm dual-wavelength fiber laser (CeramOptec GmbH of Biolitec AG, Bonn, Germany); suspension laryngoscope and laryngeal microsurgical instruments (KARL STORZ co., Tuttlingen, Germany); Storz Professional Image Enhancement System (SPIES) (KARL STORZ co., Tuttlingen, Germany).

Surgical methods

All operations were performed by one surgeon. All patients were placed in the supine position and underwent general anesthesia with intubation of the trachea, which had an inner diameter of 5.0–6.0 mm. A suitable type of self-retaining laryngoscope was placed through the mouth to fully expose the glottal area. The vocal cords were clearly exposed under the microscope, and microsurgery was performed using cold instruments or cold instruments with laser. The laser was a CO_2 laser (1.5–2 W, super-pulse mode) or 980 nm/1470 nm dual-wavelength fiber laser (980 nm 0.5–1 W, 1470 nm 1.5–2 W, super-pulse mode). During operation, the lateral microflap technique was used to cut open the mucosa longitudinally using laryngeal microsurgical scissors or a laser along the junction of the Reinke's edema and normal mucosa of the upper surface of the vocal cord. The lower surface of the vocal cords was preserved, and attention was paid to retain 2–3 mm of the anterior commissure mucosa. After the jelly-like substance in the Reinke's space underneath the mucosa was removed, the medial mucosa was replaced, and the excessive mucosa was trimmed and removed. After the mucosa flap was made, microsurgical suture of the vocal cord mucosa was performed under a self-retaining laryngoscope. All the patients underwent bilateral vocal cord surgery and mucosal microsuture at the same time.

Microsuture method of the knot pusher group was as follows (Fig. 1).

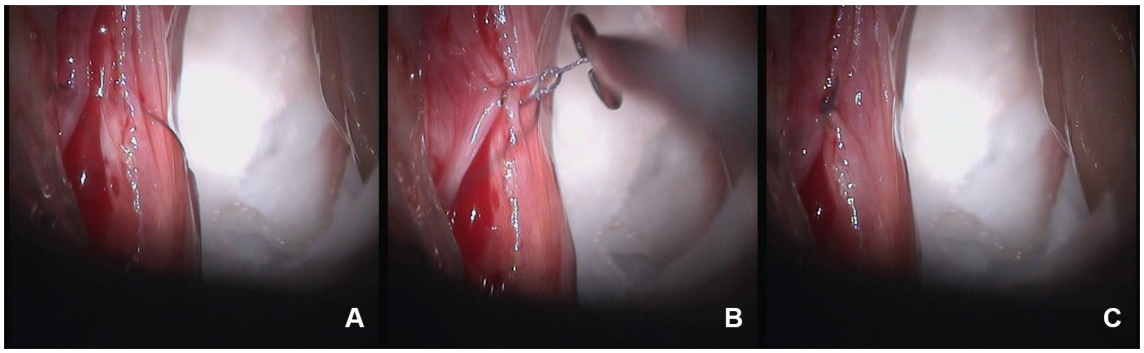

Fig. 1 Microsuture with knot pusher. **a** The thread was passed through the mucosa; **b** the knot was made outside the laryngoscope and was pushed slowly into the laryngeal cavity by the knot pusher; **c** a triple knot was made

1. One nonlocking microlaryngeal straight forceps, one laryngeal microneedle clamp and a knot pusher are used during suturing. 5–6 stitches of 6/0 vicryl suture with 8-mm long, reverse cutting, curved needle with at least 45-cm thread length is necessary.
2. The right hand holds a laryngeal microneedle clamp to hold the front 1/3 of the needle body and adjusts the position of the needle, and the needle and vocal cord form an angle of approximately 90°. When suturing the right vocal cord, the tip of the needle points obliquely to the lower left; when suturing the left vocal cord, the tip of the needle points obliquely to the upper left.
3. The microneedle clamp and needle entered the laryngeal cavity is slowly along the laryngoscope. The tail of the thread is left outside the laryngoscope to facilitate making the knot.
4. The suturing of the right vocal cord starts by inserting the needle into the mucosa of the upper surface and then passing through the mucosa flap. The suturing of the left vocal cord starts by inserting the needle into the lower surface of the mucosa flap, and then the needle is pulled out from the mucosa of the upper surface of the vocal cord; the left hand uses a microsurgical clamp to help pull the needle out of the laryngoscope.
5. The needle is pulled out of the laryngoscope while the other end of the thread is held by the assistant. After the knot is made outside the laryngoscope, it is pushed slowly into the laryngeal cavity by the knot pusher while the surgeon is holding one end of the suture and the assistant is holding the other end. The sutures are pulled tightly with an appropriate amount of force. A simple knot is tied outside the laryngoscope again, and aforementioned steps are repeated while a triple knot or surgical knot is made. At the end of the suturing, the thread is cut with microscissors close to the knot. If mucosal avulsion occurs, the mucosa needs to be trimmed and sutured again. According to the situation, two to three stitches can be performed.

Microsuture method of the two-handed tying group is as follows (Fig. 2).

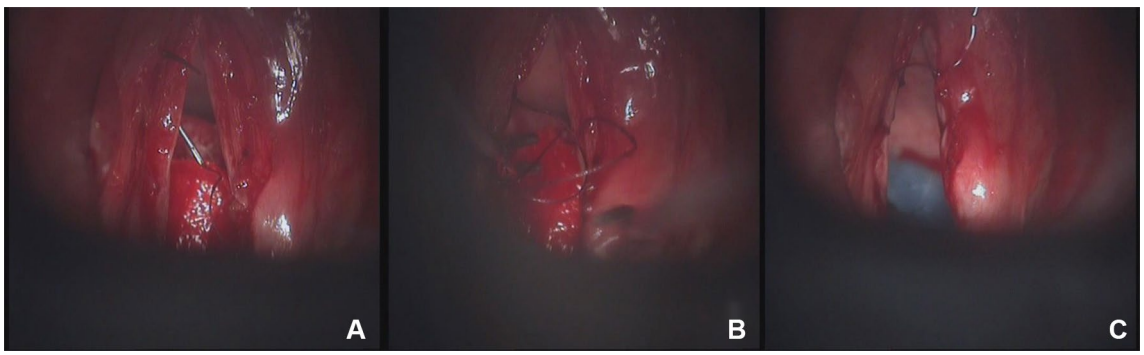

Fig. 2 Microsuture with two-handed tying technique. **a** The needle and the thread were passed through the mucosa; **b** the knot was made by two microlaryngeal curved forceps inside the laryngoscope; **c** a triple knot was made

1. One nonlocking microlaryngeal left curved forceps, one nonlocking microlaryngeal right curved forceps, one laryngeal microneedle clamp and a knot pusher are used during suturing. 1–2 stitches of 6/0 vicryl suture with 8-mm long, reverse cutting, curved needle with at least 45-cm thread length is necessary.
2. The method of holding and inserting the needle is the same as that of the knot-tying group; however, after the needle comes out and is pulled out of the laryngoscope, the thread continues to be pulled out and stops until the tail of the thread is only 4–5 cm; surgical scissors are used to cut the sutures so that the length of the tail of thread on both sides is approximately 4 cm.
3. Both the left and right hands hold a laryngeal microsurgical clamp, respectively, the clamps hold the tail of the thread to perform instrument tying in the laryngeal cavity, and a triple knot or surgical knot is made.

Evaluation indicators

The operation videos were played back to record the number of knots and time used to suture and tie each knot (the total time from the insertion of the needle until the completion of tying the knot and cutting the thread) for every patient. The average time for suturing and tying the knot and the average time for tying the knot for each patient was calculated, and the occurrence of complications was recorded. All patients underwent preoperative and 1-month and 3-month postoperative stroboscopy and fiberoptic laryngoscopy to examine the healing of the vocal cord wounds and closure of the glottis. Subjective and objective voice assessments were performed before and 3 months after surgery. Subjective assessments included voice handicap index-10 (VHI-10) scores and subjective auditory perception assessment G grade of GRBAS. Objective voice assessment included computer voice analysis and aerodynamic tests, which mainly included indicators such as the Maximum F0, Minimum F0, frequency range, jitter, shimmer, maximum phonation time (MPT), phonation threshold pressure, mean airflow rate, laryngeal resistance and peak pressure.

Results

All patients underwent successful operation. In the knot pusher group, the postoperative pathology of 19 cases was simple vocal cord Reinke's edema, and the pathology of 8 cases was Reinke's edema with vocal leukoplakia. In the two-handed tying group, the postoperative pathology of 24 cases was simple vocal cord Reinke's edema, and the pathology of 6 cases was Reinke's edema with vocal leukoplakia. No statistically significant difference was found in age, Yonekawa classification and surgical type between the knot pusher group and two-handed tying group.

No statistically significant difference was found in the average number of knots between the knot pusher group and two-handed tying group. The average time for making knots in the knot pusher group and two-handed tying group was 668.40 ± 173.73 s and 328.73 ± 121.08 s, respectively, and there was a statistically significant difference between the two groups ($p < 0.001$) (Table 1). The learning curve showed that, with the maturity of suturing and tying technique, the average time for making knots was both decreased (Fig. 3). And after the learning process of ten cases, the average time for typing knots in the knot pusher group was stabilized at approximately 280 s. However, after the learning process of ten cases, the average time for making knots in the two-handed tying group was stabilized at approximately 150 s (Fig. 4). There were two cases of mucosal avulsion in the knot pusher group, while no mucosal avulsion occurred in the two-handed tying group, and no significant difference was found between the groups (Table 1).

In the knot pusher group, there were four cases of numbness of the tongue and five cases of mucosal injury of the palatoglossal arch. In the two-handed tying group, there were two cases of numbness of the tongue and four cases of mucosal injury of the palatoglossal arch. No complications were found such as postoperative hemorrhage and vocal cord adhesion. No significant difference was noted in the overall incidence of complications between the groups (Table 1).

In both groups, it was observed that the vocal cord mucosa in patients had recovered, the vocal cord morphology was good, and the edge of the vocal cord was smooth during operation. 1 month after the surgery, it was observed that, under a stroboscope or a fiberoptic laryngoscope, the bilateral vocal cord mucosa was smooth, the sutures were partially absorbed or fell off, and the closure of the vocal cord was good. Three months after the surgery, it was observed that, the sutures were completely absorbed and fell off, the mucosa of the bilateral vocal cord was smooth, and closure of the vocal cord was good.

3 months after the surgery, the G grade and VHI-10 of patients in both groups were lower than those of the preoperative ones, and comparison showed that a statistically significant difference before and after the operation. In both groups, Maximum F0, frequency range and MPT were increased 3 months after the operation, and comparison with those before the operation showed a statistically significant difference. In both groups, jitter, shimmer, phonation threshold pressure, mean airflow rate, and peak pressure at 3 months after the operation were lower than those before the operation, and the difference from those before the operation was statistically significant. No significant difference was found between the two groups in terms of the preoperative and 3-month postoperative subjective and objective indicators (Table 1).

Table 1 Clinical feature and voice outcome data

	Knot pusher group ($n=27$)	Two-handed tying group ($n=30$)	$t(\chi^2)$	p value
Age	53.96 ± 6.08	54.13 ± 6.71	−0.1	0.921
Yonekawa classification			1.442	0.229
Grade II	11	17		
Grade III	16	13		
Surgical type			2.074	0.354
Cold instruments	4	3		
Cold instruments with CO_2 laser	23	25		
Cold instruments with 1470 nm/980 nm dual fiber laser	0	2		
No. of knotting	4.88 ± 0.84	4.86 ± 0.73	0.106	0.916
Average time for suturing and tying the knot	668.40 ± 173.73	328.73 ± 121.08	8.626	< 0.001
Average time for tying the knot	323.85 ± 52.88	159.80 ± 20.22	15.771	< 0.001
Mucosal avulsion	2	0	2.303	0.129
Complications	9	6	1.302	0.253
Preoperative voice assessment				
G	2.55 ± 0.0	2.66 ± 0.47	−0.851	0.399
Acoustic				
Maximum F0	293.29 ± 50.28	279.8 ± 51.57	0.998	0.323
Minimum F0	109.22 ± 12.8	107.66 ± 15.01	0.418	0.677
Frequency range	184.07 ± 51.10	172.13 ± 51.40	0.877	0.384
Jitter	4.26 ± 1.07	4.35 ± 1.12	−0.299	0.766
Shimmer	6.45 ± 1.29	6.41 ± 1.20	0.121	0.904
Aerodynamic				
Maximum phonation time	9.59 ± 1.15	10.08 ± 1.24	−1.525	0.133
Phonation threshold pressure	8.72 ± 1.37	8.99 ± 1.54	−0.687	0.495
Mean airflow rate	0.31 ± 0.03	0.31 ± 0.04	0.580	0.564
Laryngeal resistance	49.71 ± 8.12	47.02 ± 7.50	1.300	0.199
Peak pressure	14.58 ± 2.21	14.72 ± 2.61	−0.225	0.823
Voice handicap index-10	26.14 ± 3.38	26.73 ± 3.85	−0.607	0.547
3-month post-operative voice assessment				
G	1.18 ± 0.87*	1.13 ± 0.89*	0.220	0.827
Acoustic				
Maximum F0	416.40 ± 70.12*	405.16 ± 61.62*	0.644	0.522
Minimum F0	115.07 ± 12.91	110.46 ± 13.09	1.335	0.187
Frequency range	301.33 ± 69.61*	294.7 ± 64.88*	0.372	0.711
Jitter	2.87 ± 0.49*	2.80 ± 0.63*	0.450	0.654
Shimmer	3.62 ± 0.79*	3.44 ± 0.71*	0.932	0.356
Aerodynamic				
Maximum phonation time	15.55 ± 2.11*	15.91 ± 2.10*	−0.645	0.522
Phonation threshold pressure	6.78 ± 1.10*	6.90 ± 1.28*	−0.354	0.725
Mean airflow rate	0.25 ± 0.05*	0.28 ± 0.05*	−1.781	0.08
Laryngeal resistance	45.55 ± 7.23	46.20 ± 8.15	−0.318	0.752
Peak pressure	10.93 ± 2.08*	11.34 ± 2.14*	−0.728	0.47
Voice handicap index-10	13.18 ± 3.49*	13.63 ± 3.44*	−0.487	0.629

*$p < 0.05$, compared with preoperative voice assessment

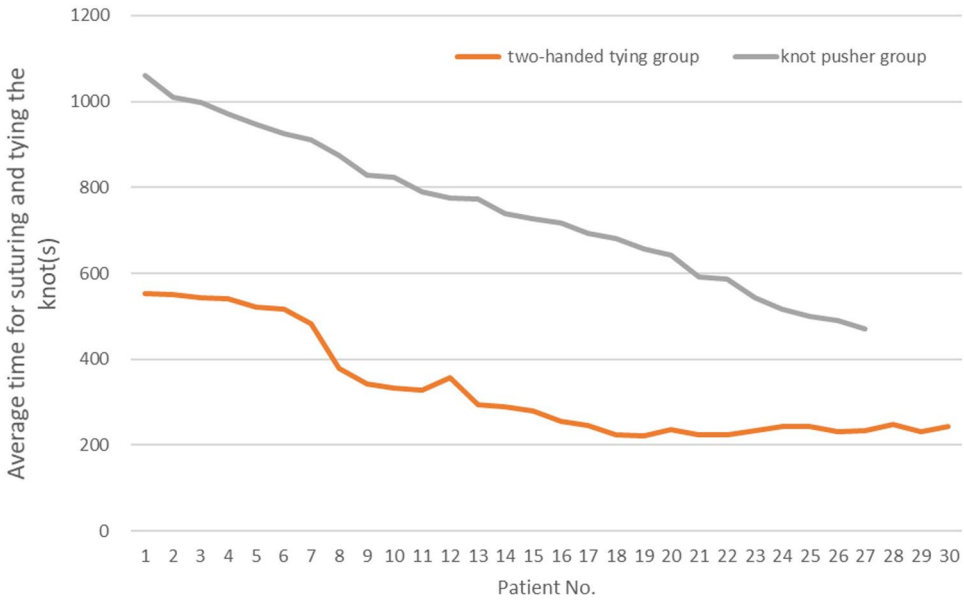

Fig. 3 Learning curves of suturing and tying in two-handed tying group and knot pusher group

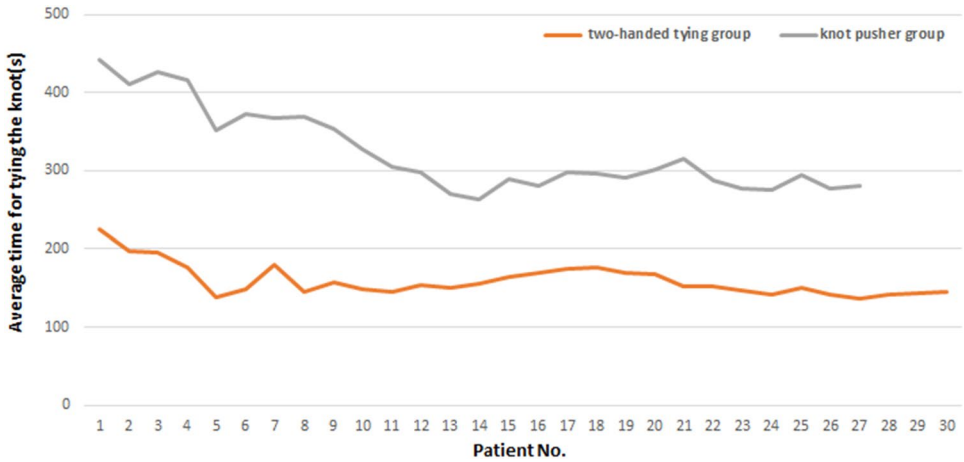

Fig. 4 Learning curves of tying the knot in two-handed tying group and knot pusher group

Discussion

Vocal cord Reinke's edema is a common clinical voice disease, which is mainly manifested by hoarseness and difficult vocalization, and talking for a long time may be accompanied by a sore throat. Its onset and progression are closely associated with the habit of smoking, as well as with a history of excessive use of the throat [2, 8]. Sometimes, it is associated with laryngopharyngeal reflux [9]. Besides lifestyle adjustments, drug treatment and voice training, microlaryngeal phonosurgery is a frequently used treatment [10–13].

The ideal microlaryngeal phonosurgery is to maintain the vocal function of the vocal cord based on complete resection of the lesion, and the vocal function of the vocal cord is closely related to the integrity of the vocal cord coating (mucosal epithelium and superficial layer of the lamina propria), especially the integrity of the epithelium. How to ensure the integrity of the vocal cord epithelium is the key to vocal cord microsurgery. For vocal cord Reinke's edema, Dursun et al. used a CO_2 laser and cold instruments in combination with surgery to carry out the treatment and suggested that removal of excessive vocal cord mucosa can reduce the risk of recurrence and provide better voice quality [14]. Therefore, it can be used as an option for surgical treatment for patients, including those who have an occupational use of their voice. The surgical procedure of Reinke's edema is to first cut the vocal cord mucosa above the surface of the vocal cord and then separate the vocal cord mucosa and submucosal tissue. After the submucosal jelly-like tissue is removed, the vocal cord mucosal epithelium is replaced, and the excessive mucosal epithelium is trimmed and removed to form a mucosa flap that covers the surgical wound. Presently, there are various strategies to treat mucosa

flaps, including direct covering by mucosa flaps, bioadhesive bonding, and microsurgical sutures [6]. Although Rebecca's animal experiments showed that the healing effect of direct covering by mucosa flaps was similar to that by adhesion or suture for patients with Reinke's edema, it is recommended that the mucosa flap be fixed if the technique allows [4]. Since the vocal cord incision is long and the mucosa flap is loose and easy to move, postoperative extubation, cough, and vocalization may lead to displacement of the mucosa flap and poor matching of the incision, likely resulting in the blockade of the epithelialization of vocal cord mucosa and a prolonged repair period. Thus, the surgical area is prone to scarring, which may affect the postoperative voice effect. Compared with bioadhesive bonding, microsurgical suture fixation of the mucosa flap is more reliable [5].

Vocal cord mucosal microsuture is a difficult operation in microlaryngeal phonosurgery. In most of the routine operations, after suturing, the knot is first tied outside the laryngoscope, and then the thread knot is slowly sent inside the laryngoscope all the way to the surface of the vocal cord mucosa by the knot pusher, and the knotting operation is repeated two to three times to complete a triple knot or surgical knot [4]. During the early stage, we used the knot pusher method for the operation. However, we found that it was very difficult to monitor the entire process under the microscope during the operation. Additionally, the tail of the thread on one side needs to be pulled by an assistant, and the force for making knots is sometimes difficult to be controlled accurately. If excessive force is used, it may lead to avulsion of the vocal cord mucosa, causing an increase in the surgical wound and affecting the quality of the postoperative voice. Therefore, in the late stage, we used the two-handed instrument for direct knotting inside the self-retaining laryngoscope, and the entire knotting process can be monitored under the microscope without the need of an assistant. The force for knotting can be accurately controlled, and no patient showed mucosal avulsion. It ensured that the mucosa was flat after the knot was tied, and no extrusion or wrinkle occurred. In this study, the recovery of the vocal cord and voice results of the patients in both groups were satisfactory, indicating that the two-handed tying technique can ensure the same quality of surgery as that of the knot pusher group.

The size of laryngeal cavity may have some influence on suturing and knotting. In our center, most of the patients with Reinke's edema who underwent surgery were male, while only five female patients underwent surgery during the same period. To avoid the influence of female patients on objective voice assessment analysis, we excluded female patients in this study. As women usually have a smaller larynx and operation field, we found making the knots in small cavity is still possible after technical maturity. But the female vocal cord is shorter, usually one or two stitches can be sutured on one side of the vocal cord.

In this study, we found that the average time of suturing and tying a single knot in the two-handed tying group is shorter than that of the knot pusher group, and the average operation time can be shortened by approximately 15 min. This is because two-handed tying technique can avoid the repeated pushing the knot by the knot pusher after the knot is tied outside the laryngoscope; thus, the operation is smoother. But this study is not a randomized controlled study, the two-handed knotting method group is later than the knot pusher group, the maturity of suture technique can shorten the time of microsuture, which will have an effect on the outcome. For this reason, we also calculated the average time for the knot's tying. The result showed after about ten cases of operation, the speed of typing will reach a certain level in both two groups, the two-handed knotting method can further shorten the knotting time.

As we know the complications of the self-retaining laryngoscope surgery, such as numbness of the tongue, might be related to the length of operation. Shorter operation time means lower incidence of complications. In our study, the incidence of complications in the two-handed tying group was relatively low, but there was no significant difference between two groups, which may be related to the smaller sample size.

The two-handed tying is more difficult than the knot pusher method. During operation, it is necessary to notice that the fixed focal length of the microscope makes it difficult to distinguish the tail of the thread. Our experience is that we do not leave an excessively long thread tail. Generally, approximately 4 cm on each side is sufficient to meet the requirement of the knotting operation using the two-handed microsurgical instrument. When tying the knot, attention should be paid that the winding of the thread by the instrument should be carried out on the vocal cord plane so that a clearer view can be ensured. For the hospitals with a better facility, the operation can be performed under a video laryngoscope. Our experience shows that after practice with approximately ten cases, hand–eye coordination can be achieved, thereby shortening the knotting time. In the future, a corresponding simulation training device can be designed to improve the operational stability of beginners in microsurgical suturing and knotting.

Conclusion

Microsuturing of Reinke's edema microflaps using the two-handed tying technique is effective and feasible; the results of this method are consistent with the knot pusher method, and the operation is more stable and smoother. After the surgeon is trained and becomes proficient, the operation time can be further shortened.

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Compliance with ethical standards

Conflict of interest The authors declared that they have no conflicts of interest to this work.

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