การเปรียบเทียบวิธีการเย็บปิดคอหอยหลังตัดกล่องเสียงที่สามารถกันการรั่วซึมได้ในสภาวะแรงดันสูงสุดโดยใช้ลำไส้เล็กสุกร

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Received: 7 พฤศจิกายน 2565
Revised: 6 ธันวาคม 2565
Accepted: 29 ธันวาคม 2565

บทคัดย่อ

ที่มาและเหตุผล : ในปัจจุบันการรักษามะเร็งกล่องเสียงและคอหอยส่วนล่างใช้การผ่าตัดเป็นหลัก แต่มักเกิดภาวะแทรกซ้อน คือ pharyngocutaneous fistula ส่งผลให้แผลหายช้า เพิ่มระยะเวลาที่ต้องอยู่ในโรงพยาบาล ต้องเลื่อนการฉายแสง/เคมีบำบัด และอาจถึงขั้นเสียชีวิตได้ วิธีการเย็บปิดคอหอยหลังการผ่าตัดกล่องเสียงเป็นปัจจัยสำคัญหนึ่งที่สามารถควบคุมได้เพื่อป้องกันการรั่วของคอหอย

วัตถุประสงค์ : เพื่อศึกษาวิธีการเย็บคอหอยที่สามารถป้องกันการรั่วได้ดีที่สุดหลังผ่ากล่องเสียง โดยเปรียบเทียบระหว่างวิธีเย็บแบบ Connell, interrupted Lembert, continuous Lembert และ simple interrupted

รูปแบบและวิธีการศึกษา : การศึกษานี้เป็น Experimental study ที่ใช้ลำไส้เล็กสุกรแทนคอหอยมนุษย์ โดยทำการเย็บลำไส้แบบ Connell, interrupted Lembert, continuous Lembert และsimple interrupted กลุ่มละ 30 ตัวอย่าง รวมเป็น 120 ตัวอย่าง บันทึกเวลาที่ใช้ในการเย็บของแต่ละวิธี หลังจากนั้นทำการอัดลมเข้าไปในโพรงลำไส้ และวัด burst pressure เก็บข้อมูลด้วยค่าเฉลี่ย(mean) และส่วนเบี่ยงเบนมาตรฐาน(SD) วิเคราะห์ข้อมูลทางสถิติโดยใช้ One-way analysis (ANOVA), Multiple comparison test, Fisher's exact test (P-value<0.05)

ผลการศึกษา : พบว่าวิธีเย็บแบบ Connell(155.87 ± 44.45 mmHg) ทนต่อแรง burst pressureได้มากที่สุด โดยมากกว่าวิธี interrupted Lembert(122.90 ± 42.57 mmHg) และsimple interrupted(79.97 ± 39.28 mmHg) อย่างมีนัยสำคัญทางสถิติ และใช้เวลาในการเย็บที่น้อยกว่าวิธีอื่นอย่างมีนัยสำคัญทางสถิติอีกด้วย

สรุปผลการศึกษา : จากการทดลองเปรียบเทียบวิธีการเย็บคอหอยหลังตัดกล่องเสียง 4 วิธี คือ Connell, interrupted Lembert, continuous Lembert และsimple interrupted ด้วยลำไส้เล็กสุกร วิธีเย็บแบบ Connell ได้เปรียบในเรื่องของเวลาในการเย็บที่น้อยกว่าวิธีอื่น และยังทนต่อแรง burst pressure ได้สูงสุดอีกด้วย อย่างไรก็ตามการศึกษานี้ไม่ได้ครอบคลุมถึงความทนต่อแรงตึง การตีบของคอหอยหลังเย็บ และปริมาณเลือดที่มาเลี้ยงรอยต่อ ดังนั้นจึงควรมีการศึกษาเพิ่มเติม โดยเฉพาะอย่างยิ่ง การศึกษาในผู้ป่วยจริงต่อไป

คำสำคัญ : pharyngocutaneous fistula, burst pressure, suture technique

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A Comparative Study on the Suture Method after Total Laryngectomy that Provide no Leakage under Highest Tension in Swine Small Intestine

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Received: 7 November 2022
Revised: 6 December 2022
Accepted: 29 December 2022

ABSTRACT

Background: Pharyngocutaneous fistula is one of the most catastrophic complications after surgical treatment for neoplasm of larynx or lower pharynx. It may result in poor wound healing, prolonged hospitalization, and delayed radiotherapy/chemotherapy, or eventually death. Suture technique in constructing a neopharynx is a main controllable factor in decreasing the incidence of pharyngocutaneous fistula.

Objectives: To compare four commonly used suture techniques after total laryngectomy (Connell, interrupted Lembert, continuous Lembert, and simple interrupted) that provides highest burst pressure.

Methodology: This is an experimental study. Cadaveric swine intestines were recruited (30 per group). Each suture technique was performed in each group. The time spent for sutures were recorded. The burst pressure was measured using air leak test. All data were presented as mean and standard deviation (SD) and analysed using One-way analysis (ANOVA), Multiple comparison test, and Fisher's exact test. The P-value <0.05 was considered statistical significance.

Results: The statistically significantly ($P < 0.05$) highest burst pressure was achieved using the Connell technique (155.87 ± 44.45 mmHg) compared tointerrupted Lembert (122.90 ± 42.57 mmHg), and simple interrupted (79.97 ± 39.28 mmHg) In addition, the mean time spent for completing the sutures were also significantly shortest ($P < 0.05$) for the Connell technique (287.77 s)

Conclusion: The Connell technique provided the highest leak pressure and lowest time spent for constructing the neopharynx. However, our study did not study the effects of each suture

technique on luminal stenosis, tensile strength and blood supply. Further study should be conducted *in vivo*.

Keywords: pharyngocutaneous fistula, burst pressure, suture technique, laryngectomy

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INTRODUCTION

Laryngeal cancer is common, as the 13th most common cancer in men and the 2nd most common head and neck cancer worldwide,[1]. In Thailand, the incidence of laryngeal and pharyngeal cancers has been increasing, particularly owing to the high percentage of smokers which is about 19% of all adults,[2]. The incidences of laryngeal and hypopharyngeal cancer were 0.94% and0.44%,[3], respectively. Current treatments include laryngeal surgery, radiotherapy, chemotherapy การรักษามี systemic therapy??and surgery combined treatment,[4].

The main complication after laryngeal surgery is pharyngocutaneous fistula, causing saliva leakage through the pharyngeal junction (neopharynx). Leakage usually occurs after swallowing saliva and food, when the pressure in the neopharynx is highest. It occurs in 8%-22% of cases [5].ขอ reference Consequently, the surgical wounds heal slowly. The incidence of wound infection is also high, potentially resulting in a long period of antibiotic use. ขอ reference หรือตรวจสอบว่า การเกิด malnutrition เป็นสาเหตุ หรือเป็นผลตามมา Furthermore, patients may need a long duration of nasogastric intubation and longer hospital stays, resulting in poor quality of life. Moreover, chemotherapy may have to be postponed, resulting in a higher incidence of cancer recurrence after surgery. All of these collectively increase the cost of treatment,[6], and death may occur as a consequence of complications such as the rupture of the carotid arteries,[7]

Treatments for pharyngocutaneous fistulae include supportive therapy and surgery. Currently, supportive therapy is commonly recommended and includes pressure dressing, tube feeding, wound drainage, and antibiotics for suspected or confirmed infection until the fistula spontaneously closes. Half of the pharyngocutaneous fistulae close within 14 days, and 75% close within 4 weeks. In cases that pharyngocutaneous fistulae do not close within one month, surgery is recommended,[8].

Effort should be made to prevent pharyngocutaneous fistula. Risk factors include hypopharyngeal diseases, suture techniques, chemotherapy, radiation, cancer stage, malnutrition, hypothyroidism, positive surgical margins and type of pharyngeal closure,[8-10].

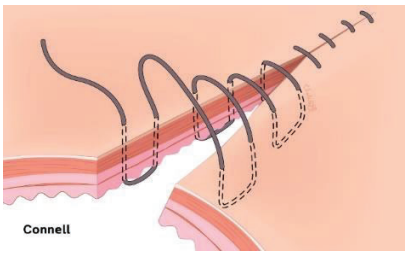
In practice, nasogastric tube feeding is given for 7 – 14 days to prevent increased pressure in the pharynx during the lag phase of anastomosis healing (the phase that the wound has the lowest level of accumulated collagen and minimal strength),[11].

However, using nasogastric tubes for a long period could be uncomfortable and cause gastroesophageal reflux. One study found that removing nasogastric tubes and resuming normal eating early (<7 days after surgery) was not associated with the occurrence of pharyngocutaneous fistula,[12].

Hence, selecting suturing techniques that can effectively prevent leakages may help physicians allow patients to begin normal eating earlier. Appropriate suture techniques must be easy, fast, and watertight (have adequate tensile strength) and ensure good blood circulation around the wound,[13].

Currently, four suture techniques are commonly used to repair the neopharynx after laryngectomy, i.e., Connell (picture1), Simple interrupted (picture2), Interrupted Lembert (picture 3) and Continuous Lembert techniques (picture 4). Lembert, a commonly use technique in repair neopharynx, is an inverting suture technique that the stitches includesubmucosal layer. ขอ check อีกครั้งในรูป It may be interrupted or continuous. Connell is an inverting continuous technique that the stitches include all layers. Another difference between Connell and continuous Lembert is that the Connell anchors the stitches longitudinally while Lembert does transversely,[14].

There have been few studies on suture techniques after laryngectomy aiming to reduce leakage. Moreover, these studies have been inconclusive and there are no studies examining the burst pressure achieved by the Connell suture technique compared to other techniques. Hence, this study was conducted in order to find the suture technique that can provide maximum wound strength, comparing among four suture techniques by measuring the burst pressure in a swine small intestine model. The result may be applicable for laryngeal surgery



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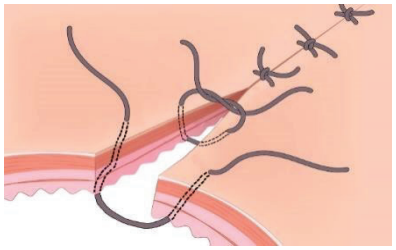
Picture1 Connell

Connell was continuous inverted suture by passing the needle from the serosa through all layer into lumen. The needle then was directing from inside through into outside of the same side. The other site was done as same technique



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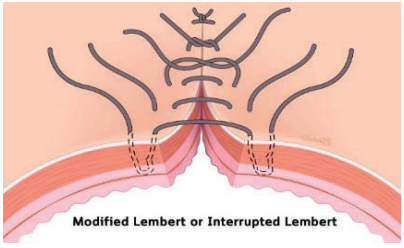
Picture2 Simple interrupted

Simple interrupted was interrupted suture by passing the needle from outside through all layer then passing the needle from other side into outside.



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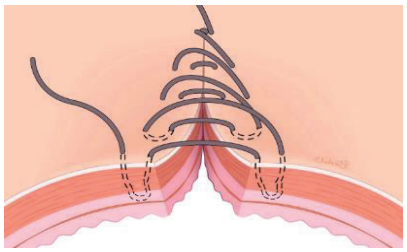
Picture3 Interrupted Lembert



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Picture4 Continuous Lembert

Lembert was continuous or interrupted suture by passing the needle from outside through submucosal layer then passing to outside of same side. The other site was done as same technique then silk was tied or continuous.

METHODS

This study was approved by ethic committee, Navamindradhiraj University (exempt: COE 29/2019 and was funded by Navamindradhiraj University Research Fund (วจ. สนธ. 07/2563).

Outcome

Primary outcome was burst pressure achieved from each of the four suture techniques measured by air leak test in vitro,[15]. The secondary outcome was the time spent to complete the suture procedure.

Experimental tissues

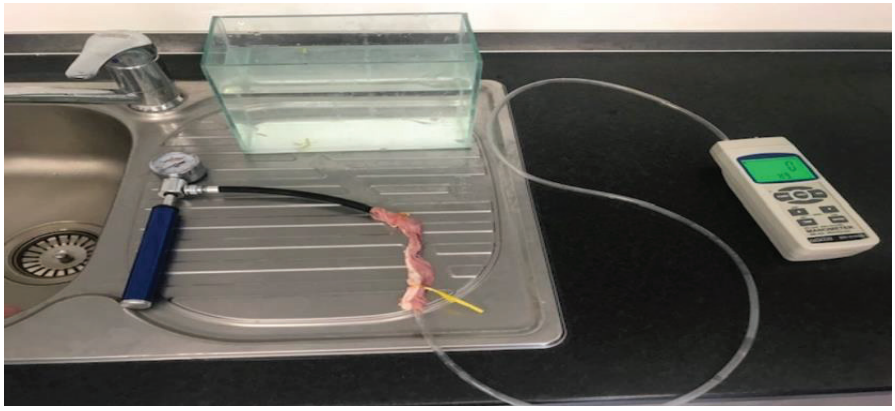
We obtained cadaveric swine small intestine within 24 hours after being slaughtered that had a thickness of 0.8–1.2 mm. The damaged or abnormal intestines such as rough or otherwise abnormal intestinal walls were not used. The intestines were randomly divided into four groups to compare the Connell, interrupted Lembert, continuous Lembert, and simple interrupted suture techniques.

Sample size

Because there are no available previous relevant studies from which we could infer appropriate sample sizes for comparing burst pressure achieved from various suture techniques, the sample size in this study was estimated with G Power software *v.*3.1.9.4, which estimates the sample size needed for testing with one-way Analysis of Variance (ANOVA) at a significance level of α = 0.05, a power of 90%, and an effect size of 0.4 (corresponding to a large effect size),[16]. The total sample size calculated by the program was at least 96 animals (with 24 samples per group). Thus, we included 30 swine small intestine per group, with a total sample size of 120.

Surgical procedures

The swine small intestines were cut into 10-cm-long pieces of uniform thickness. A 2-cm cut along the axis of the small intestine was applied to the lumen on the anti-mesenteric side of each piece. The cuts were then sutured by one surgeons ข defined ประสบการณ์การผ่าตัด; Diploma, Thai Subspecialty Board of Facial Plastic and Reconstructive surgery, surgical experience in laryngectomy 35 cases, who randomly selected techniques among the four tested suture techniques. Vicryl 4-0 round needles (ETHICON W9106) were used. The distance between the stitches was 0.2 cm. After suturing the cuts, the ends of each piece were tightly closed with wires. (picture5)



(The figure was taken by author)

Picture5 shows the rubber tube placed in both end of the intestine. The left end was connected to manometer. The right end was connected to pressure transducer. Both ends were closed with wires for ensuring no air leakage

Then, the proximal end of each piece was connected to a digital manometer (DIGICON MN910-SD) . The manometer tube was inserted 2 cm away from the wound site. The distal end of each piece was connected to an air blower. Then, the intestines were immersed in water to find any leakages. Air was blown into each intestine until it leaked out through the stitches. Air leak test was performed manually by slowly increasing the intraluminal pressure (over 1 minute), The time from complete suturing to pressure test is less than 30 minutes. The highest pressure before the leakage was measured and was defined as the burst pressure. Although saline test is more physiologic than air teak test, we decided to use air leak test because it is more sensitive and practical to detect the leakage,[15]. The pressures were measured separately with the suturing station by another investigator who did not reveal the suture methods. Therefore, this study is a blind technique.

Statistics

The mean value and standard deviation of the burst pressures were calculated for each group and then statistically analysed with one-way ANOVA, multiple comparison test (Bonferroni), or Fisher's exact test, as appropriate.

RESULTS

The average thickness of the intestines in each group is shown in table 1. The thickness of the intestines was not significantly different among the tested groups ($P > 0.05$. Nevertheless, the mean diameter of the intestines in the continuous Lembert group was significantly longer than that of the other three groups (Table 2)

Table 1 Comparison of the thickness of the small intestine in each group

	n	Thickness (mm) (Mean ± SD)	*P*-value*
Connell	30	1.01 ± 0.15	
Simple interrupted	30	1.04 ± 0.25	
Continuous Lembert	30	0.96 ± 0.08	
Interrupted Lembert	30	1.04 ± 0.13	0.218
* One-way ANOVA, statistically significant ($P < 0.05$)			

Table 2 Comparison of the diameter of the small intestines in each group.

	n	Diameter (cm) (mean ± SD	p-value (oneway ANOVA)	p-value for Multiple comparison test (Bonferroni)						Median (IQR)
				C vs S	C vs CL	C vs IL	S vs CL	S vs IL	CL vs IL	
ไม่ถูกที่			0.011	1.000	0.014	1.000	0.054	1.000	0.119	
Connell	30	2.23 ± 0.29								2.2 (2.1 - 2.4)
simple Interrupt	30	2.26 ± 0.33								2.4 (1.9 - 2.5)
continuous Lembert	30	2.44 ± 0.15								2.45 (2.3 - 2.5)
interrupted Lembert	30	2.28 ± 0.25								2.3 (2.1 - 2.4)

C: Connell, S: simple interrupted, IL: interrupted Lembert, CL: continuous Lembert

* Statistically significant ($P < 0.05$)

Table 3 Comparison of burst pressure (mean ± SD) achieved by each suture technique.

S	n	Burst pressure (mmHg)	p-value (oneway ANOVA)	p-value for Multiple comparison test (Bonferroni)					
				C vs S	C vs CL	C vs IL	S vs CL	S vs IL	CL vs IL
			<0.001	<0.001	0.876	0.028	<0.001	0.002	0.940
Connell	30	155.87 ± 44.45							
simple interrupt	30	79.97 ± 39.28							
continuous Lembert	30	139.17 ± 49.81							
interrupted Lembert	30	122.90 ± 42.57							

C: Connell, S: simple interrupted, IL: interrupted Lembert, CL: continuous Lembert

*Statistically significant (p<0.05)

Although the average burst pressure achieved from the Connell technique was higher than that of the continuous Lembert technique, they were not significantly different (P = 0.876). It is worth noting that the burst pressure achieved from the Connell technique was significantly higher than that of the interrupted Lembert and simple interrupted techniques (Table 3).

Considering the time spent on sutures, we found that the Connell technique needed a significantly shorter time than that of the other techniques (283.77 ± 48.85 s, $P < 0.05$). This was followed by the continuous Lembert, simple interrupted, and interrupted Lembert techniques (Table 4).

Table 4 Comparison of suturing time spent in each group.

	n	Suturing time (sec) (mean ± SD)	p-value (oneway ANOVA)	p-value for Multiple comparison test (Bonferroni)					
				C *vs* S	C *vs* CL	C *vs* IL	S *vs* CL	S *vs* IL	CL *vs* IL
			<0.001*	0.001*	0.002*	<0.001*	1.000	1.000	1.000
Connell	30	283.77 ± 48.85							
simple interrupt	30	342.00 ± 50.79							
continuous Lembert	30	341.77 ± 73.50							
interrupted Lembert	30	353.63 ± 61.88							

C: Connell, S: simple interrupted, IL: interrupted Lembert, CL: continuous Lembert

*Statistically significant (p<0.05)

When comparing the leakage position, we found that the leakage positions in the Connell group were more often at the ends of the tied intestines that were not related to the suture stitches. The interrupted Lembert and continuous Lembert techniques had more leakages through the stitches than the other techniques did. The simple interrupted technique had more leakages between the stitches than the other techniques (Table 5).

Table 5 Leakage sites

	Connell	simple interrupt	continuous Lembert	interrupted Lembert	p-value*
	n (%)	n (%)	n (%)	n (%)	
leakage site					<0.001**
needle hole	4 (13.33)	14 (46.67)	20 (66.67)	23 (76.67)	
between suture	5 (16.67)	16 (53.33)	6 (20.00)	3 (10.00)	
not related to suture¶	21(70.00)	-	4 (13.33)	4 (13.33)	

*Fisher's exact test, statistically significant ($P < 0.05$)

¶ Not related to sutures: leakage site at the distal end of the intestine or other locations than the suturing site

Discussion

Here, we found that the Connell technique provided the highest burst pressure comparing to the interrupted Lembert, continuous Lembert, and simple interrupted techniques. This may be because the Connell technique is the inversion technique results in a watertight seal,[14]. Furthermore, this technique is a continuous suture technique, therefore the tensile forces between the stitches are distributed equally and result in few leakages,[17] In addition, the incidence of postoperative adhesion is lower,[18].

The Connell technique was previously compared with clips in goat large intestines using laparoscopic surgery. In that study, the wounds healed more effectively and quickly than did clips,[19]. Hence, this technique is excellent because it can prevent leakages effectively. Moreover, Connell technique is superior than Lembert technique in term of holding higher burst pressure. Because it can spread tension along wound edge more than Lembert technique does.

For the continuous Lembert technique, we found that this technique provided the second-highest burst pressure. These results are consistent with a retrospective study in colonic anastomosis conducted by Eickhoff et al.,[17], who found that the continuous technique could prevent leakages more effectively than the interrupted technique because it reduces the eversion of the edges of the wound and, as mentioned above, continuous techniques result in waterproof seals and can distribute forces equally. This may explain the higher burst pressure in the continuous Lembert group than the interrupted Lembert group. Nonetheless, continuous suture techniques require skilled surgical assistants to effectively suture wounds. Practically, continuous techniques may not be more effective than interrupted techniques if surgical assistants are not able to control the tensile force in each stitch to share the tension between the stitches equally.

For the simple interrupted technique, we found that this technique provided the lowest burst pressure. This is also consistent with the study by Eickhoff et al,[17] but study by Kieves et al.,[20] found that simple interrupted had higher burst pressure than simple continuous but was not significantly. However, simple continuous and Simple interrupted may practically was not significant difference,[21].

Even though the interrupted Lembert technique was also an interrupted technique, it provided higher burst pressure than that of the simple interrupted technique. This can be because the interrupted Lembert results in more inversions at the edges of the wounds than does the simple interrupted technique.

We found that the Connell and continuous Lembert techniques required the shortest suturing times. This is consistent with the study by Phillips et al,[22], in which the continuous technique took a shorter time than did the interrupted technique. However, the most important confounder is the skill of the surgeon for each technique. Therefore, this study uses only one surgeon to perform the procedure.

Although staplers are typically used for repairing the neopharynx, they remain expensive (clips~ 2,000-4,000 Bath/case VS vicryl ~ 128-170 Bath/case). Staples cannot be used for all patients. Therefore, effectively suturing by hand is still appropriate for patients in Thailand. Still, the suture technique with the highest burst pressure might not be the best technique. For instance, very close or tight stitches for increasing the burst pressure might increase the possibility of ischaemia, leading to poor wound healing and finally leakages,[23].

Thus, further studies should be conducted; in particular, actual patients should be studied in order to observe the long-term results after suturing wounds,[11]. Moreover, modified Gambee suture; extensively used suture method in gastrointestinal tract anastomosis, interrupted suture, penetrate to submucosal layer, minimize mucosal eversion, [19,24] should compare with Connell suture because of Gambee suture was significant highest burst pressure from the study by Kieves et al,[20]. In addition to factor that affect leakage, T or Y-shaped closure pattern provides higher leakage than horizontal closure due to three-point junction,[10].

Another factor that should be considered for an appropriate suture technique includes the risk for pharyngeal stenosis, such as primary lesion and pharyngeal remnant. We may choose augmentation technique (flap reconstruction) than primary closure in high-risk stenosis cases,[25,26]. Furthermore, the appropriate suture technique will be dependent on the skills and experience of the surgeon,[27].

One important limitation of this study is that this study was performed in cadaveric swine intestines and therefore other factors influencing the incidence of pharyn gocutaneous fistula in viable tissues were not studied. For example, other factors that affect the adequacy of the blood supply, factors influencing tissue healing (e.g., nutritional status, hypothyroidism, chemotherapy, radiation),[28] Radiation therapy induced mio-initial myointimal fibrosis. Thereafter, fibroblast decreased and hypovascular atherosclerosis was occurred,[29]. These factors also lead to pharyngocutaneous leakage.

We used the small intestines of pigs instead of human pharynx because it is easily available in the market. This study chose pig intestine because its thickness is approximately similar to human neopharynx,[30]. Although other animal intestines (chicken, cow) have similar number of intestinal layer but their thickness are different from human neopharynx. In our study, human neopharynx is 0.92-1.08 cm. in thickness whereas pig intestine is 0.8-1.5 cm. in thickness. Moreover, both pig intestines and human pharynxes have submucosal layer that comprise numerous collagens. The initial anastomosis strength depends on abundant collagen in this layer,[31]. Nevertheless, there are some different physical properties between these two tissues. Thus, the finding in this study might not be accurately relevant to the human pharynx. However, the findings from this study can be applied for comparative suturing technique in human pharynx in perspective of higher burst pressure and lesser time spent for suture. The results may provide guidelines for further studies. In addition, large intestine cannot be used in this study because taenia coli has different tension character from small intestine.

- Limitation

- cadaveric swine intestines therefore other factors influencing the incidence of pharyngocutaneous fistula in viable tissues were not studied.

- strength

- only one surgeon to perform the procedure

CONCLUSION

We conclude that the Connell technique provided the best leak pressure and speed of application for constructing the neopharynx. However, our study did not study the aspects regarding luminal stenosis, tensile strength and blood supply. Further study should be conducted *in vivo*.

ACKNOWLEDGEMENT

I would like to acknowledge and give my warmest thanks to Asst Prof Anan kultaweesup and my supervisor, Asst Prof Sarinya Urathamakul who gave me the possibility to complete this report. Their guidance and advice carried me through all the stages of writing my project.

Contributors concept

US and CP study designed, planned, managed the study and participated in the discussion and interpretation results. CP wrote the initial draft. US contributed to editing manuscript. All authors approved the final version.

Funding

Support provided by Navamindradhiraj University Research Fund (วจ. สนธ. 07/2563).
No financial relationships with any organization that might have an interest in the submitted work.

Ethics approval

approved by ethic committee, Navamindradhiraj University (exempt: COE 29/2019)

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