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Comparison of three-dimensional vs. two-dimensional assisted thoracoscopy for recurrent laryngeal nerve lymph nodes dissection in esophagectomy: a retrospective study

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Abstract

Background This study aimed to explore the clinical value of 3D video-assisted thoracoscopic surgery in dissecting recurrent laryngeal nerve lymph nodes in patients undergoing minimally invasive esophagectomy.

Methods A retrospective cohort study was conducted on 205 patients, including 120 males, who underwent esophagectomy from May 2018 to May 2020 in the Department of Thoracic Surgery at the Affiliated Huai'an No.1 People's Hospital of Nanjing Medical University. Perioperative parameters, including intraoperative blood loss, operation time, the number of dissected recurrent laryngeal nerve lymph nodes, the incidence and degree of postoperative recurrent laryngeal nerve injury, the volume of postoperative thoracic drainage, and postoperative complications, were compared between the 3D and 2D groups.

Results There were no significant differences in the preoperative baseline data between these two groups ($P > 0.05$). The number of dissected recurrent laryngeal nerve lymph nodes in the 3D group was significantly higher than in the 2D group ($P < 0.05$). The operation times were significantly shorter in the 3D group than in the 2D group ($P < 0.05$). The volume of thoracic drainage in the first 2 days was significantly less in the 3D group than in the 2D group ($P < 0.05$).

Conclusions Compared to the 2D system, the application of 3D video-assisted thoracoscopic surgery in minimally invasive esophagectomy can increase the number of dissected recurrent laryngeal nerve lymph nodes and ensure safety. Additionally, it can reduce the duration of the operation, decrease early postoperative thoracic drainage volume, and promote patient recovery.

Keywords 3D thoracoscopy, Esophagectomy, Recurrent laryngeal nerve lymph node dissection

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Background

Esophageal squamous cell carcinoma (ESCC) is a prevalent digestive tract tumor in China, with the number of new cases and deaths each year constituting more than half of the global [1]. Currently, Treatment for ESCC includes surgical resection, radiotherapy, chemotherapy, or immunotherapy, and surgical resection remains the primary treatment modality for ESCC. Traditional open esophagectomy is associated with substantial trauma and a higher incidence of postoperative complications. With the advancement of endoscopic techniques, minimally invasive esophagectomy (MIE) is being increasingly adopted by thoracic surgeons [2, 3]. Common endoscopic esophagectomy include the McKeown procedure and minimally invasive Ivor-Lewis procedure [4]. While lymphatic metastasis of ESCC often occurs in a skip pattern, the bilateral recurrent laryngeal nerve (RLN) lymph nodes remain the primary metastatic site of ESCC [5]. The RLNs are located in the relatively narrow space of the superior mediastinum, which makes them susceptible to injury during dissection. Additionally, right thoracic approach in MIE further complicates the left RLN lymph node dissection. Damage to the RLN remains a common complication during MIE, manifesting as postoperative hoarseness, coughing or choking while drinking, swallowing dysfunction, and even asphyxia [6, 7]. Therefore, both achieving bilateral recurrent laryngeal nerve lymph nodes dissection and avoiding recurrent laryngeal nerve injury remain unresolved issues in current esophageal surgery. Three-dimensional (3D) thoracoscopy offers superior depth perception compared to two-dimensional (2D) thoracoscopy, providing specific advantages in esophageal cancer surgery [8]. Therefore, this study compared the clinical data of patients who underwent MIE with 3D thoracoscopy and 2D thoracoscopy in our hospital from May 2018 to May 2020. The aim of this study was to evaluate the advantages and disadvantages of 3D thoracoscopy in bilateral recurrent laryngeal nerve (RLN) lymph node dissection in MIE, and provide practical guidance for clinical application.

Methods

Patients

This study is a retrospective study. The inclusive criteria were: (1) preoperative confirmation of ESCC by gastroscopy and pathology, with clinically evaluated as resectable ESCC (staging as T1b-T3, N0-N1, M0, according to the 8th edition of the UICC/AJCC); (2) underwent thoracoscopic combined with laparoscopic esophagectomy (McKeown procedure), gastroesophageal anastomosis was at the left neck; (3) no prior neoadjuvant treatment. Exclusion criteria were: (1) patients with a history of pulmonary tuberculosis, tuberculous pleurisy, pneumonia, or prior thoracic surgery; (2) conversion to open esophagectomy during operation; (3) incomplete case data; (4) presence of severe cardiac or pulmonary dysfunction, or history of malignancy in other organs. Based on above criteria, a total of 205 patients were included in this study. According to the different thoracoscopic equipment, patients were divided into two groups: 2D thoracoscopy group (112 patients with 69 males) and 3D thoracoscopy group (93 patients with 51 males). Study protocols were approved by the Ethics Committee of the Affiliated Huai'an No.1 People's Hospital of Nanjing Medical University and conducted according to the principles expressed in the Declaration of Helsinki (World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects 2013). All patients and their caregivers provided informed consent. A flow chart summarizing the selection of patients is shown in Fig. 1.

Surgical procedure

Patients were given general anesthesia and underwent single-lumen endotracheal intubation. Lay in the left lateral position with a 30° anterior tilt. Thoracic part of MIE needed to establish artificial pneumothorax of right thoracic cavity to get the surgical field. Observation port was established at the seventh intercostal space along the anterior axillary line. The primary operating port was positioned at the fourth intercostal space along the anterior axillary line, while auxiliary operating ports were established at the sixth and tenth intercostal spaces along the mid-axillary line.

3D Group: The German Storz 3D thoracoscope system was utilized. Both the surgeon and assistants wore 3D glasses. Dissection of the esophagus commenced from the superior margin of the azygos vein arch within the mediastinal pleura. The right RLN lymph nodes were dissected, followed by the ligature and division of the azygos vein arch. The esophagus was mobilized downstream along the azygos vein arch to the esophageal hiatus. Lymph nodes were dissected para-esophageal, subcarinal area, under trachea, and bronchus. Finally, the left RLN lymph nodes were dissected. Following completion of thoracic procedures, the patient was repositioned into a supine position. Under laparoscopy, the stomach was dissociated and intra-abdominal lymph nodes were dissected. Following that, a cervical incision was made, and the cervical esophagus was dissociated and lymph nodes were dissected. Next, the separated stomach was extracted through a small incision in the upper abdomen to create a tube-shaped stomach. Then the tube-shaped stomach was elevated to the neck through the esophageal bed pathway for end-to-side esophagogastrostomy using a side-to-side stapler. Subsequently, one duodenal feeding tube and one gastric decompression tube were nasally inserted. After the conclusion of operation, patient

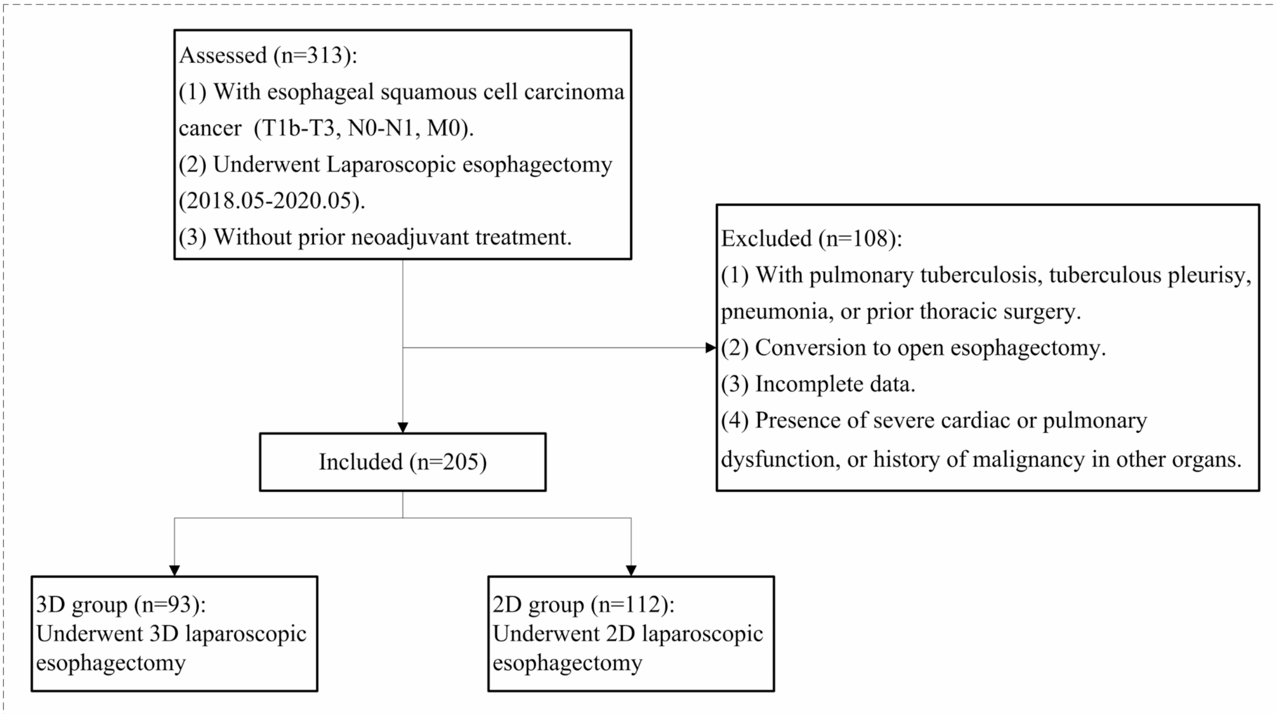

Fig. 1 The study flowchart

was transferred to the recovery room for observation. Upon awakening with stable vital signs, the patient was returned to the ward and received standard clinical pathway interventions including infection prevention, hemostasis, and nutritional support.

2D group: The Japanese Olympus 2D thoracoscope system was utilized. Surgeon and assistants did not need to wear 3D glasses. The operation procedure was the same as the 3D group.

Hollow-out method of RLN lymph nodes dissection: In this study, RLN lymph nodes dissection was performed using the "hollow-out method" [9]. After opening the mediastinal pleura and tracing along the right vagus nerve trunk, the right RLN was located below the lower edge of the right subclavian artery. Under thoracoscopy, tissue separation forceps were used to pull and separate tissues bluntly, hollowing out the lymph nodes and adipose tissue beside the right RLN. Sharp dissection with thoracoscopic scissors was performed to completely remove the lymph nodes and adipose tissue beside the right RLN. When dissecting the left RLN lymph nodes, the esophagus was lifted by pulling the esophageal suspension band, and the left RLN was located behind the left side of the trachea. Tissue separation forceps were used to pull and separate tissues bluntly, hollowing out lymph nodes and adipose tissue beside the left RLN. Sharp dissection with thoracoscopic scissors was performed to remove the lymph nodes and adipose tissue beside the left RLN. If minor bleeding from small blood vessels interferes with visualization, hemostasis can be achieved by gently pressing with a small gauze strip.

Observation parameters and assessment standards

Preoperative data for two patient groups were compared, including age, gender, smoking history, comorbidities, tumor location and pathological stage. Then a comparison of intraoperative parameters of two groups was conducted, including intraoperative blood loss, operation time, postoperative thoracic drainage volume, and the number of dissected RLN lymph nodes (according to postoperative pathology). Additionally, statistical comparison was performed for the incidence of postoperative complications (including severe lung infection, arrhythmia, anastomotic leakage and postoperative RLN injury). The severity of RLN injury was graded according to previous study [10, 11]: mild cases exhibited transient hoarseness due to temporary nerve paralysis, with symptoms typically recovered within 3 to 7 days; moderate cases were characterized by coughing and impaired production of high-pitched sounds during eating, with symptoms persisting; severe cases featured symptoms such as breathing difficulties and loss of voice, which did not alleviate spontaneously.

Follow-up

The main follow-up methods included outpatient visits and telephone calls. Patients were followed up with one telephone call at the first week and one month after

Table 1 Patient characteristics ($N=205$)

Characteristics		3D group ($n=93$)	2D group ($n=112$)	Statistical value	P value
Age(years)		62.2 ± 9.1	63.4 ± 9.6	t = 0.914	0.362
Gender	Male	51	69	χ^2=0.958	0.382
	Female	42	43		
Smoking history		46	60	χ^2=0.344	0.558
Comorbidities	Diabetes	10	12	χ^2=0	0.993
	Hypertension	19	24	χ^2=0.031	0.861
	Coronary heart disease	5	7	χ^2=0.071	0.79
Tumor location	Upper Thoracic	18	28	χ^2=0.945	0.623
	Middle Thoracic	54	61		
	Lower Thoracic	21	23		
Pathological stage (TNM stage)	IA	8	11	Z = 0.562	0.574
	IB	15	12		
	IIA	23	38		
	IIB	20	27		
	IIIA	17	14		
	IIIB	10	10		

discharge, and subsequently every three months for outpatient visits.

Statistical analysis

Statistical analysis of the data in this study was performed with SPSS 27.0 software (IBM Corporation, Armonk, NY, USA). Continuous data were presented as mean±standard deviation ($\bar{x} \pm s$). The comparison of continuous data was conducted with Student's t-test, while analysis of variance (ANOVA) was employed for comparisons among multiple groups. Non-parametric tests were utilized while variances among populations were unequal. For categorical data, comparisons of rates were performed with the Pearson chi-square test, and rank-sum tests were used for ordinal data. A probability (P) value of <0.05 was considered statistically significant.

Results

A total of 205 patients (120 females and 85 males) with ESCC were enrolled in this study. The average age of the patients was (62.8±9.4) years. 112 patients were enrolled in the 2D group, while 93 patients were enrolled in the 3D group. There was no significant difference in the baseline data of these two groups, including age, gender, tumor location, pathological stage, and comorbidities ($P>0.05$). Detailed information was shown in Table 1.

The number of dissected RLN lymph nodes was significantly higher in the 3D group (left: 4.19±1.85, right: 3.74±1.62) compared to the 2D group (left: 3.40±1.78, right: 3.12±1.54; all $P<0.05$). Additionally, the surgical duration was shorter in the 3D group compared to the 2D group (3D 198.8±21.4 min vs. 2D 205.7±23.9 min, $P=0.036$). In early postoperative period (days 1–2), patients in the 3D group (d1: 170.4±50.4 ml, d2: 150.2±38.6 ml) had significantly less thoracic tube drainage compared to those in the 2D group (d1: 200.3±57.8 ml, d2: 162.7±47.2 ml, $P<0.05$). There was no significant difference in intraoperative blood loss between these two groups ($P>0.05$). Detailed operative characteristics are listed in Table 2.

Table 2 Operative characteristics of patients ($N=205$)

Variables		3D group ($n=93$)	2D group ($n=112$)	Statistical value	P value
Number of dissected RLN lymph nodes	Right	3.7 ± 1.6	3.1 ± 1.5	t = 2.828	< 0.01*
	Left	4.2 ± 1.9	3.4 ± 1.8	t = 3.065	< 0.01*
	Total	7.9 ± 2.3	6.5 ± 2.4	t = 4.280	< 0.01*
Operation time (min)		198.8 ± 21.4	205.7 ± 23.9	t = 2.154	0.032*
Blood loss (mL)		97.6 ± 42.5	104.8 ± 48.1	t = 1.123	0.263
Postoperative thoracic tube drainage (ml)	D1	170.4 ± 50.4	200.3 ± 57.8	t = 3.904	< 0.01*
	D2	150.2 ± 38.6	162.7 ± 47.2	t = 2.052	0.041*
	D3	160.5 ± 44.9	157.9 ± 46.6	t = 0.409	0.683
	D4	110.9 ± 38	106.8 ± 42.5	t = 0.709	0.479
	D5	87.1 ± 33.6	93 ± 44.9	t = 1.038	0.301

RLN: recurrent laryngeal nerve

Then a comparison of postoperative complications of these two groups was performed, as listed in Table 3. The incidence and severity of RLN injury in the 3D group were both lower than those in the 2D group, but there was not significant difference ($P>0.05$). Severe RLN injuries did not occur in either group. Symptoms such as hoarseness and coughing in patients with mild injuries spontaneously resolved within 10 days postoperatively. Patients with moderate injuries gradually recovered normal voice through voice training within 1–2 months after operation. There was no significant difference in the incidence of postoperative pulmonary infection, arrhythmia,

Table 3 RLN injuries and complications of patients ($N = 205$)

Variables		3D group ($n = 93$)	2D group ($n = 112$)	Statistical value	P value
RLN injuries (%)	None	88(94.62)	101(90.18)	Z = 1.188	0.235
	Mild	4(4.30)	8(7.14)		
	Moderate	1(1.08)	3(2.68)		
	Total	5(5.38)	11(9.82)	1.395	0.238
Pulmonary infection (%)		4(4.30)	8(7.14)	0.318	0.573
Arrhythmia (%)		3(3.23)	6(5.36)	0.159	0.69
Gastroesophageal anastomotic fistula (%)		3(3.23)	4(3.57)	0.018	0.892

RLN: recurrent laryngeal nerve

or gastroesophageal anastomotic fistula between the two groups ($P > 0.05$). Please refer to Table 3 for details.

Discussion, and conclusions

The anatomical structure of the esophagus possesses its own peculiarities. The presence of horizontal and vertical lymphatic vessels within the submucosal and muscular layers of esophagus forms a unique lymphatic network, leading to the unpredictable and irregular pattern of lymph node metastasis in ESCC [12]. However, due to the high rate of lymph node metastasis in the bilateral RLN lymph nodes in thoracic ESCC, bilateral RLN lymph node dissection is an indispensable step in esophagectomy [13]. Given the proximity of RLNs to the esophagus, it is highly susceptible to be injured while dissociating esophagus and dissecting RLN lymph nodes. Once injured, vocal cord function may be compromised, leading to postoperative hoarseness and affecting the patient's ability to cough and clear phlegm, which can subsequently result in respiratory complications such as pulmonary infection, aspiration pneumonia, and asphyxia [11]. Therefore, enhancing the efficiency and safety of RLNs lymph node dissection is crucial for patients undergoing esophagectomy.

Currently, thoracoscopic MIE (McKeown procedure) has become the mainstream surgical approach in the treatment of ESCC and is widely practiced worldwide [14]. The advantages of thoracoscopic esophagectomy include minimal intraoperative bleeding, reduced trauma, decreased postoperative drainage, alleviated pain, and faster recovery. However, 2D laparoscopy lacks depth perception and spatial awareness, making it relatively prone to inadvertent injury to the RLNs. In contrast, 3D thoracoscopy provides a three-dimensional view and high-definition stereoscopic imaging, offering greater magnification and visual clarity compared to 2D laparoscopy. Several studies have compared the application of 3D and 2D laparoscopy in esophagectomy in patients with ESCC [15–18]. The results indicate that 3D laparoscopic esophagectomy offers advantages over 2D laparoscopy in terms of surgical duration, intraoperative bleeding, and other indicators. Nevertheless, there is currently a lack of research specifically investigating the effectiveness of RLN lymph node dissection by 3D laparoscopy. Due to the distinct pattern of lymph node metastasis in ESCC, lymph node dissection is pivotal in esophagectomy and is directly linked to postoperative prognosis. Numerous studies have shown that an increased number of dissected lymph nodes favorably influences survival [19, 20], underscoring the importance of standardized lymph node dissection in esophagectomy [21]. As lymph node dissection becomes more common in esophagectomy, researchers have noted that esophageal cancer can metastasize to the RLNs lymph nodes even at early stages, and early dissection of these nodes may help reduce the risk of recurrence and enhance the accuracy of nodal staging in early-stage ESCC [22]. And a real-world study in ESCC patients identified Adequacy of RLNs lymph node dissection is an important prognosticator for improved overall survival and recurrence-free survival in ESCC patients [23]. Another study involving 406 patients also demonstrated that the number of dissected upper mediastinal lymph nodes in esophagectomy, including RLNs lymph nodes, is directly associated with improved long-term prognosis [24]. The results of our study demonstrate a significant advantage of 3D laparoscopy over 2D laparoscopy in the dissection of RLN lymph nodes. Specifically, the 3D group exhibited a higher number of dissected RLN lymph nodes, including those around both left and right RLN, as well as a greater total number of dissected RLN lymph nodes compared to the 2D group ($P < 0.05$). This notable advantage may be attributed to the specific technique of RLN lymph node dissection employed in this study. In this study, the approach used for dissecting RLN lymph nodes is the " hollow-out" method [9]. During the lymph node dissection process, dissecting forceps are utilized to hollow out the tissue surrounding the nerve into block-like structures, followed by sharp dissection of the lymph nodes by laparoscopic scissors or other "cold" instruments. The improved 3D visualization and depth perception provided by 3D laparoscopy result in clearer anatomical layering of the hollowed-out tissue, nerves, and blood vessels. This allows the surgeon to conduct lymph nodes dissection more swiftly and thoroughly. In this study, the 3D group exhibited a significantly reduced operation time compared to the 2D group (3D 198.8 ± 21.4 min vs. 2D 205.7 ± 23.9 min, $P < 0.05$). Moreover, our practical experience suggests that the reduction in operation time mainly occurred during thoracic operation. However, due to the limitations of retrospective study, a more detailed comparison was not feasible in this study.

Furthermore, results of this study indicate that there was no significant difference in intraoperative blood loss between these two groups. And postoperative thoracic tube drainage of the first and the second day were both significantly reduced compared to the 2D group ($p<0.05$). Additionally, postoperative RLN injury in the 3D group was comparable to the 2D group. This may be attributed to the more detailed anatomical visualization provided by the 3D mode. The high-definition view offered by 3D laparoscopy enables effective differentiation of nerves, blood vessels, and surrounding tissues, thus reducing the risk of injury and bleeding during sharp dissection of lymph nodes and nerves, and lowering the risk of microvascular bleeding. Moreover, there was no significant difference in the incidence of postoperative complications, including pulmonary infection, arrhythmia, and gastroesophageal anastomotic fistula, between the 3D and 2D groups. Therefore, these results indicate that 3D laparoscopy is sufficiently safe.

Although this study highlights the significant advantages of 3D thoracoscopic surgery in dissecting RLNs lymph nodes during MIE, practical experience has also identified some drawbacks associated with 3D laparoscopy. Firstly, all surgeons are required to wear 3D glasses, and there is a period of adaptation necessary for visual adjustment. Some surgeons may face challenges in adapting to the 3D stereoscopic view and may require an adaptation period, with some even experiencing continued difficulty in acclimating to the 3D view, thereby hindering the performance of 3D laparoscopic surgery. Additionally, 3D surgery imposes higher demands on the placement of the display screen and the brightness of the operating room, necessitating specialized surgical equipment, operating rooms, and surgical teams, which may impede rapid widespread adoption. However, glass-free 3D technology holds promise in addressing these issues [25]. Moreover, this study has limitations. Although the sample size included in this study was relatively large, the study's limitations, including its single-center, retrospective, non-randomized design, and the relatively homogeneous patient population, precluded more detailed subgroup comparisons for many indicators. Many questions still require answers from future prospective studies.

In conclusion, under proficient mastery of thoracoscopic surgical techniques, the application of 3D thoracoscopic surgery system in MIE can significantly enhance the efficiency of RLN lymph nodes dissection while ensuring safety. Additionally, it can reduce the volume of postoperative thoracic tube drainage and accelerate patient recovery. Therefore, 3D thoracoscopic surgery system stands as a powerful tool for thoracic surgeons, warranting further research and improvement.

Author contributions

Qi Wang and Sheng Zhong contributed to the conception of the study. Qi Wang, Jintong Ge and Sheng Zhong wrote the main manuscript text. Qi Wang, Jintong Ge, Hua Wu and Qingquan Wu performed the data analyses. Qi Wang, Jintong Ge and Sheng Zhong contributed to the data collection. Sheng Zhong and Qingquan Wu performed the surgery. All authors reviewed the manuscript.

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Data availability

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Approval and consent to participate Study protocols were approved by the Ethics Committee of the Affiliated Huai'an No.1 People's Hospital of Nanjing Medical University and conducted according to the principles expressed in the Declaration of Helsinki (Approval No. KY-2024-334-01) (World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects 2013). This study is a retrospective study, and each patient provided written informed consent to participate in relevant retrospective research when signing the preoperative surgical consent form. Clinical trial number: not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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