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Comparison Between Ultrasound- and Bronchoscopy-guided Percutaneous Dilational Tracheostomy in Critically Ill Patients

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Abstract: To compare the clinical efficacy, safety, and prognosis between fiberoptic bronchoscopy-assisted percutaneous dilatation tracheostomy and real-time ultrasound-guided percutaneous dilatation tracheostomy, and evaluate their clinical application value for further clinical use. From January, 1, 2018, to November 1, 2019, 64 newly admitted patients in our hospital undergoing percutaneous dilatation tracheostomy were included in the study. They were divided into two groups, the random fiber bronchoscopy-assisted percutaneous dilatation tracheostomy group (control group) and the modified bedside ultrasound-guided percutaneous dilatation tracheostomy group (study group), according to the random number table method, with 32 patients in each group. Subsequently, the intraoperative and postoperative complications and clinical prognostic indicators of the two groups were compared. There were statistically significant differences between the two groups in the number of punctures, puncture time, and incidence of air sac leakage ($P<0.05$); however, the number of punctures and the incidence of air sac leakage were lower in the study group than in the control group. There was no statistically significant difference between the two groups in the postoperative transient hypotension, transient acute hypoxia, atelectasis, infection, and excessive phlegm at the surgical incision, subcutaneous emphysema, and other complications ($P>0.05$). Real-time ultrasound-guided percutaneous dilatation tracheostomy can reduce the number of punctures in the air sac with no further complications and clinical prognosis.

Keywords: Percutaneous Dilatation Tracheostomy, ICU, Fiberoptic Bronchoscopy, Ultrasound

1. Introduction

Percutaneous dilatation tracheostomy (PDT) is one of the most common surgeries performed in critically ill patients, which can reduce throat damage, lower the risk of sinusitis, and promote oral hygiene, improving the patient's comfort level and convenience in communication, facilitating nursing care provided by nursing staff, and maintaining deglutition. Moreover, a tracheostome can be easily inserted again when detached by accident and can be easily withdrawn from mechanical ventilation [1]. Relevant studies have shown that early tracheostomy was associated with the reduced incidence of ventilator-associated pneumonia, decreased mechanical ventilation and length of stay in the intensive care unit (ICU), and reduced healthcare cost and hospital mortality [2].

At present, PDT is performed under direct vision assisted by a fiber bronchoscope in clinical practice. Nevertheless, a fiberoptic bronchoscope cannot identify the anatomical structure of the neck and prevent some complications, such as the presence of vascular lesions or thyroid puncture; additionally, a fiberoptic bronchoscope has a number of technical issues, and its equipments are not easily cleaned and sterilized. A fiberoptic bronchoscope must be within reach during tracheostomy, and clinicians must be trained on how to

use this tool, which restricts its clinical use in critical care.

Recently, Ultrasound has considered a visualization technology, is increasingly used because of the following advantages: it is safe, portable, and noninvasive and can be repeatedly used during an operation, which can be used to evaluate airway anatomy and assist in tracheostomy, improving the patients' success rate of operation and reducing complications [3]. However, clinical studies on real-time ultrasound-guided transcutaneous dilatation tracheostomy are small and limited by their sample size an their quality of date, and its clinical effects and application values are unclear. This study aimed to investigate whether the ultrasound-guided PDT is superior or equivalent to bronchoscopy-assisted PDT with regard to procedural-relate and clinical.

2. Materials and Methods

2.1. General Data

This was a prospective randomized double-blind controlled study. Patients admitted in the ICU of our hospital from January 1, 2018, to December 1, 2019, were included, all of whom needed to undergo PDT tracheostomy according to clinical needs. In this study, patients were randomly divided into the fiberoptic bronchoscopy-assisted PDT group (control group) and the modified bedside ultrasound-guided PDT group (study group), with 32 cases in each group. Patients who died during the observation period due to disease (unrelated to complications of PDT) were excluded from this study, and the number of patients in the same group was supplemented with 32 cases according to the random number method.

Patients with the following characteristic were included in the study: patients with endotracheal intubation requiring PDT. However, patients with the following characteristics were excluded: patients aged less than 18 years; patients with anatomical deformation of the neck, giant nodular goiter, severe coagulation dysfunction, surgical site infection, and unstable cervical fractures; and patients with family members who refused to participate in the study. This study was approved by the hospital ethics committee, and all patients and guardians provided informed consent for inclusion in the study. All operations were performed in the ICU by physicians with greater than 5-year experience in performing percutaneous dilated tracheostomy.

2.2. Methods

2.2.1. Ultrasound-guided Percutaneous Dilatation Tracheostomy (PDT) (Study Group)

Regarding the location of the incision site, all patients were routinely fully sedated by administering propofol combined with fentanyl (Ramsay score, 4–5 points), and the operation was performed using the Portex percutaneous tracheostomy catheter kit. The patient assumed a supine position, with shoulder on the pillow, neck overextended, and head in the median position and tilted back to fully expose the trachea. The thyroid cartilage, cricothyroid membrane, and cricoid cartilage were determined by performing preliminary cervical ultrasonography (LOGIQ E portable color ultrasound of General Electric Company of the United States); subsequently, the middle position of the trachea, the distance from the anterior wall of the trachea to the skin, the position of the thyroid isthmus and its association with the 2–4 trachea cartilage ring, and the vascular distribution in the surgical area were determined. The ultrasonic probe must not forcefully press the neck tissue during the examination, but Doppler ultrasound could be used to focus on the observation of blood vessels and comprehensively determine the optimal puncture site. A surgical marker should be used to mark the tracheal striations and segments.

When adjusting the position of the endotracheal catheter, the ultrasonic probe was placed on the section of the long axis of the trachea to locate and adjust the position of the endotracheal catheter; subsequently, the ultrasonic probe was withdrawn to the puncture area. If the imaging was not clear, the air sac was filled with normal saline when necessary to facilitate the ultrasonic observation of the position of the catheter tip; simultaneously, the airway was measured, and the appropriate model of tracheostomy catheter was selected.

When confirming the position of the puncture needle and guide wire, the ultrasonic probe was wrapped with a sterile sleeve, and the "out-of-plane method" (short axis method) was used to guide the puncture needle into the trachea vertically in the middle of the 2–4 cartilage rings, and the side wall of the trachea was punctured, and the insertion depth should be the preoperative measurement result plus 1 cm. When air bubbles or sputum was extracted usually, the puncture needle was necessarily inclined to the foot, the cannula was fixed, and the puncture needle was pulled out and subsequently guided the J-shaped guide wire into the tracheal cavity through the cannula. The guide wire should be inserted while monitoring the puncture needle enhanced development mode as far as possible to avoid entering the space between the subcutaneous tissues and anterior wall of the trachea. After the trocar was pulled out, ultrasound was used again to observe the entry point and direction of the guide wire and to determine whether the guide wire was inside the trachea. The anterior neck skin was transversely cut with an incision of approximately 2 cm, the subcutaneous tissue and tube wall were expanded along the guide wire using an expander, and the anterior airway wall and airway were expanded along the guide wire using an expansion forceps. Finally, the tracheostomy tube was placed along the guide wire and fixed, and the postoperative routine bedside chest X-ray examination was performed.

2.2.2. Fiberoptic Bronchoscopy-assisted PDT (Control Group)

All patients were routinely fully sedated with the administration of propofol combined with fentanyl (Ramsay score, 4–5 points), and the operation was performed using the Portex percutaneous tracheostomy catheter kit. The patient assumed a supine position, with shoulder on the pillow, neck overextended, and head in the median position and tilted back to fully expose the trachea. The puncture needle was

placed between the 2–4 tracheal rings of the median line of the neck, with a towel soaked in disinfectants for disinfection; the trachea cannula was withdrawn 17–18 cm from the incisors, and a lateral incision (approximately 2 cm) was created on the skin in the anterior portion of the neck. The fiber bronchoscope (Olympus BFP40) was used to guide the puncture positioning after the trocar extracted bubbles in the trachea from the midpoint of incision, and the puncture needle was detected under direct vision; when necessary, the position of the trachea cannula should be adjusted, the needle pulled out, the J-shaped guide wire guided into the airway lumen, and the guide wire within the tracheal cavity under the fiber bronchoscope confirmed. Subsequently, the trocar should be extracted, the subcutaneous tissue and trachea wall along the guide wire dilatated using an expander, and the anterior airway wall and airway along the guide wire expanded using a spreading forceps. Finally, the tracheostomy tube was placed over the guide wire and fixed after confirmation directly under the fiberoptic bronchoscopy. Postoperative routine bedside chest X-ray examination was performed.

2.2.3. Observation Indicators and Time

The following patients' basic information before surgery was recorded: sex, age, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, time of intubation before surgery, platelet (PLT) count, and time of partial thromboplastin activation; during the surgery, the patients' heart rate, blood pressure, and pulse oxygen saturation were continuously monitored, and the operation time, incision length, air sac leakage rate of the trachea cannula, and success rate of the first tracheostomy tube were recorded. The bleeding amount and complications around the postoperative incision and airway (hypoxemia, subcutaneous emphysema, phlegm spillage at incision) were recorded; the clinical prognostic indicators included mechanical ventilation time, extubation time for tracheostomy tube, length of ICU stay, and mortality. The observational period started from the time the patient was admitted in the ICU until 7 days after PDT. All operations were performed in the ICU by physicians with greater than 5-year experience in percutaneous dilated tracheostomy.

2.2.4. Statistical Methods

The normality test was conducted to all data first. Normal distribution was represented by mean ± standard deviation, while non-normal distribution was represented by interquartile range. Counting data were expressed in ratios or rates. The *t*-test was used to compare the measurement data of the two groups of normal distribution, and the *Mann-Whitney U* test was used to compare the measurement data of the two groups of non-normal distribution. The rates were compared using X^2 test. $P<0.05$ was considered to be statistically significant, and all statistical treatments and plots were performed using the Statistical Package for the Social Sciences (SPSS) version 19.0 software (SPSS Inc., Chicago, IL).

3. Results

A total of 64 consecutive patients were included in our study. There were no statistically significant differences in sex, age, preoperative mean arterial pressure, APACHE Ⅱ score, body mass index, admission diagnosis, time of activated partial thromboplastin, PLT count, prothrombin time, atelectasis, and other aspects between the two groups ($P>0.05$). See Table 1 for details.

Table 1. *Comparison of basic data between the two groups.*

Indicator	Study group (n=32)	Control group (n=32)	P value
Sex (%)			0.802
Male	18 (56.3)	17 (53.1)	
Female	14 (43.7)	15 (46.9)	
Age (year)	74.9±11.5	70.5±9.8	0.099
MAP (mmHg)	65.3±8.1	64.3±8.6	0.634
APACHE Ⅱ score (score)	21.2±3.7	20.0±3.7	0.178
BMI (kg/m^2)	21.3±2.8	20.0±3.7	0.248
Length of mechanical ventilation before PDT (d)	8.4±2.8	7.7±3.0	0.334
APTT (s)	36.1±5.1	35.6±5.0	0.712
PT (s)	12.5±1.4	12.7±1.7	0.573
PLT (10^9)	165.2±53.5	163.6±55.8	0.969
Atelectasis case (%)	2 (11.1)	0 (0)	0.146
ICU admission diagnosis cases (%)			0.368
Respiratory diseases	3 (9.4)	7 (21.9)	
Cardiovascular diseases	6 (18.8)	6 (18.8)	
Neurological lesions	20 (62.5)	14 (43.8)	
Trauma	3 (37.5)	5 (15.6)	

There were statistically significant differences between the two groups in the number of punctures, puncture time, and incidence of air sac leakage ($P<0.05$), while the number of punctures and the incidence of air sac leakage were lower in the study group than in the control group. See Table 2 for details.

Table 2. *Comparison of intraoperative observation indicators between the two groups.*

Indicator	Study group (n=32)	Control group (n=32)	P value
Length of incision (cm)	1.6±0.2	1.7±0.2	0.161
Number of punctures	1 (1,1)	2 (1,2)	0.042
Initial success rate cases (%)	28 (87.5)	25 (78.1)	0.320
Puncture time (s)	421.1±118.4	333.3±88.4	0.017
Air sac leakage cases (%)	6 (18.8)	18 (56.3)	0.002
Hemorrhage during operation cases (%)			
No evident bleeding	24 (75)	22 (68.8)	
Bleeding not serious and stopped spontaneously after catheterization	6 (18.8)	5 (25.0)	0.830
Excessive bleeding, which could be stopped by compression	2 (6.3)	2 (6.3)	
Massive bleeding, requiring surgical treatment	0 (0.0)	0 (0.0)	

There was no statistically significant difference in the occurrence of postoperative transient hypotension, transient acute hypoxia, atelectasis, infection, and excessive phlegm at the incision, subcutaneous emphysema, and other complications between the two groups (P>0.05). See the details in Table 3.

Table 3. *Comparison of postoperative complications and clinical prognostic indicators between the two groups.*

Indicator	Study group (n=32)	Control group (n=32)	P value
Transient hypotension cases (%)	7 (21.9)	8 (25.0)	0.768
Transient acute hypoxia cases (%)	6 (18.8)	2 (6.3)	0.131
Pulmonary atelectasis cases (%)	6 (18.8)	2 (6.3)	0.131
Infection at the incision cases (%)	3 (9.4)	1 (3.1)	0.302
Excessive phlegm at the incision n (%)	4 (12.5)	8 (25.0)	0.200
Subcutaneous emphysema n (%)	1 (3.1)	3 (9.4)	0.302
Mechanical ventilation time after tracheostomy (d)	14.5±4.3	16.2±5.2	0.351
Length of stay in the ICU (d)	17.2±6.5	16.5±5.8	0.304
ICU mortality rate n (%)	5 (15.6)	4 (12.5)	0.719

4. Discussions

Studies have shown that 8.5% of the ICU patients underwent traditional tracheostomy and 16.8% of them underwent percutaneous tracheostomy [4]. Traditional tracheostomy requires high specialized technology, corresponding surgical instruments, and strict surgical environment, and this procedure has the following disadvantages: it produces large incision, has long operation time, and results in several complications, such as bleeding, respiratory cardiac arrest, pneumothorax, and granuloma formation [5]. Therefore, it cannot be widely performed in the ICU. In recent years, along with the development of percutaneous tracheostomy technology, ICU tracheostomy has been widely used because it has the following advantages: it produces a small incision, is a relatively simple operation, and results in less blood loss. However, percutaneous tracheostomy has several disadvantages including the following: a significantly deep trocar puncture will damage the posterior wall of the trachea and even cause tracheoesophageal fistula; inaccurate positioning may cause the tracheostomy not to be completed at one time; repeated operation may increase the probability of trachea injury; and intraoperative and postoperative massive bleeding may be observed during percutaneous tracheostomy [6, 7]. It is particularly important to further reduce the incidence of complications.

At present, PDT is mainly performed directly under a fiberoptic bronchoscope, and the related studies have shown that this method can achieve real-time dynamic monitoring of puncture position and depth; guarantee the proper placement of the puncture needle, guide wire, and expanders located right in the midline of the trachea to avoid a dilator from damaging the mucosa of the posterior wall of trachea; and prevent the tracheostomy tube from being inserted into the trachea, which is particularly essential for patients with an abnormally structured neck. Nevertheless, a fiberoptic bronchoscope cannot identify the anatomical structure of the neck and prevent some complications. In the process of puncture, the lens end of the fiberoptic bronchoscope may be damaged, resulting in the damage of the bronchoscope and certain healthcare economic loss. Even under the direct vision using the fiberoptic bronchoscope, the puncture needle cannot properly avoid the air sac, and the risk of injury to the air sac is significantly possible, resulting in the risk of aspiration of the upper airway secretions, thereby increasing the occurrence of hypoxemia [8]. The fiberoptic bronchoscope must be within reach during tracheostomy, and the clinicians must be properly trained on how to use this tool, which restricts its clinical use in critical care.

Visualization technology has been developing rapidly in clinical practice in recent years. Considered as a visualization technology, ultrasound has been widely used because it has the following advantages: it is safe, portable, and noninvasive and can be repeatedly used in an operation, improving patient's success rate of operation and reducing complications when used to evaluate airway anatomy and assist in tracheostomy [3]. At present, studies on ultrasound-guided percutaneous tracheostomy in China are only few, while ultrasound is only used to optimize the location of the incision points and avoid any injury in the

blood vessels and/or thyroid gland according to the relevant studies abroad [9-11].

Therefore, the use of ultrasound is relatively limited, and the whole process visualization of ultrasound is not fully provided; thereby, it is not considered as a standard tool in PDT. In recent years, as the functions of bedside ultrasound equipments are continuously improving, specifically the function of puncture needle enhanced development (needle), and studies regarding airway application are constantly developed, theoretical basis for the implementation of modified ultrasound-guided PDT has been provided [12, 13]. According to the Guidelines for Management of Tracheostomy in Adults in the ICU in France in 2018, neck ultrasound should be frequently used during percutaneous tracheostomy (Grade 2+/ strongly agreed) [14].

The results of this study showed that real-time ultrasound-guided PDT could increase the puncture time, but reduce the number of intraoperative punctures and the incidence of air sac leakage, and fiberoptic bronchoscopy-guided PDT had insignificant differences regarding other complications and prognosis from that of real-time ultrasound-guided PDT. A series of postoperative complications were statistically insignificant. Compared with the previous studies, the simple use of ultrasound to optimize the location of puncture points could lower the incidence of air sac puncture and bleeding [15]. Real-time ultrasound-guided PDT resulted in repeated exploration and localization due to the patient's physical condition, intraoperative cough, and other conditions, relatively increasing the operation time, but did not increase the incidence of atelectasis and hypoxemia.

This study has some limitations. Regarding the location of the puncture needle or guide wire, the development of only one point or part of the puncture needle can be observed under ultrasound, which cannot clearly show all anatomical structures and adjacent relations; therefore, multiple explorations to multiple sections are required. Meanwhile, this study is a single-center study with a small sample size, which may not significantly prove the results of the study.

In conclusion, real-time ultrasound-guided PDT can reduce the number of punctures and the incidence of air sac leakage, but does not affect other complications and clinical prognosis.

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