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Original Article

Ultrasound Versus Bronchoscopy Guided Percutaneous Dilatational Tracheostomy: A Comparative Analysis

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Abstract

Objective: To compare procedure efficacy and postoperative complications of ultrasound-guided vs. bronchoscopy guided percutaneous dilatational tracheostomy, among obese ICU patients.
Study type, settings & duration: The prospective, randomized & comparative study was conducted in critical care department of Services Hospital, Lahore from April 2020 to April 2021.
Methodology: A total of 52 ICU patients were assigned into two groups (Group A-25 patients, and Group B-27 patients). Group A patients underwent ultrasound-guided percutaneous dilatational tracheostomy (PDT) and group B under conventional bronchoscopy guidance. In both groups, Ciaglia's method of PDT was used among both groups. Patients were monitored for procedure time, number of punctures, peri and post-procedural complications: Bleeding, injury to nearby structures, hypoxemia, arrhythmias, difficulty to ventilate, pneumothorax, surgical emphysema, loss of airway, tracheal cartilage fracture and a new lung infiltrate, etc.
Results: Intra-procedural complications were noted among four obese patients from both groups, i.e 1/15 (6.6%) in group A, and 3/14 (21.4%) in group B. The operation time was comparatively less in A as compared to group B. However, hospitalization duration in both the groups remained the same i.e 28 days. No postoperative complications were noted in either group. There were no conversions to surgical tracheostomy and deaths.
Conclusion: Ultrasound-guided procedure is superior to bronchoscopy guided PDT among obese ICU patients with a low percentage of intra- and post-operative complications.
Key words: Percutaneous dilatational tracheostomy, ultrasound, bronchoscopy, obesity.

Introduction

Lately, an increase in the use of tracheostomy procedure has been observed in patients who are severely ill and require prolonged ventilation in ICU settings. This increase has compelled the medical world to introduce an alternative, in the form of percutaneous dilatational tracheostomy (PDT) to the typical surgical tracheostomy (ST). In PDT, being a least invasive procedure, a tracheostomy tube is placed in the trachea without immediate surgical visualization through serial dilatations. Procedure is performed easily at patient's bedside along with tracking the patient's vitals at same time. In ICU, PDT is now deemed as a practical option in contrast to ST.[1]

Traditionally, PDT is performed under the bronchoscopy guidance as a safety collateral method to locate the accurate position of puncture in trachea. Bronchoscopic visualization steers the real-time insertion of needle into the trachea by preventing trauma to tracheal walls and affirming the desired placement of tracheostomy tube in lumen.

Percutaneous dilatational tracheostomy (PDT) is an invasive procedure where a tracheostomy tube is placed after creating a tracheal stoma through serial dilatation, instead of creating it surgically. Tracheostomy tube insertion is an intervention which is commonly being performed

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Authors Contribution

HN, SMAN & AA conceptualized the project. HN, AA, SZ, ARK & WA did the data collection. HN, SMAN, AA & ARK also did the literature search. HN, SMAN, SZ & WA also performed Statistical analysis. Drafting, revision & writing of manuscript were done by HN, SMAN, SZ, ARK & WA.

in ICUs where prolonged ventilation is anticipated, as the former is associated with higher rates of ICU mortality and compromised post-ICU discharge health associated quality of life.[2]

There are different types of PDT procedures; Ciaglia's tracheostomy, Fantoni's trans-laryngeal tracheostomy, Griggs percutaneous technique, Balloon dilatational tracheostomy and Frova's percutaneous tracheostomy.[3] All of the mentioned types are similar in puncturing the trachea with a needle and guidewire insertion thereafter. Trachea can be punctured at two different sites; between the 1st & 2nd and/or 3rd & 4 tracheal rings. According to few studies, the puncture between the 3rd & 4th tracheal rings is linked with minimal chances of unintentional trauma to the aberrant vessels and the surrounding anatomical sites, in case there are anatomical irregularities.[4]

Ciaglia in 1985,[5] described the first percutaneous dilatational tracheostomy technique using a small skin incision and serial dilators which were slided over the Seldinger wire. The technique turned out to be safe and quick. Later, a commercial kit which used this technique was made available and the procedure was carried out with lower complications rate, both short and long term. At least three adjustments have been made to date in the technique to improve it from every aspect: firstly the use of serial dilators have been replaced by a single curved (Ciaglia's Blue Rhino) dilator; secondly, frequent use of fiberoptic bronchoscopy has become an integral part of the procedure; and thirdly, tracheal interspace of cannulation has been moved one or two tracheal spaces caudal from the cricoid cartilage.

The efficacy of replacing many dilators with a single dilator in PDT was assessed in a prospective randomized study[6] where the population sample were trauma patients. Even though neither of the methods had any significant complexities, using a single dilator technique had a benefit of not requiring to change the dilator repeatedly. This had lessened the loss of tidal volumes by the time tracheal tube was made ready to be inserted.

On the other hand, bronchoscopy does not always accurately distinguish the cervical anatomical sites. To overcome this issue, recently real-time ultrasound has been used in PDT. For tracheostomy, usage of ultrasonographic visualization was reported for the first time in 1995 [7] whereas, the use of real-time ultrasound in tracheostomy was described in 1999.[8]

By using ultrasound, the interventionist can now clearly visualize the path where the needle is moving. This will help to prevent the injury to tracheal wall and the surrounding sites. Ultrasound-guided PDT may be explicitly used in cases in which there are factors involved that make the procedure difficult to execute, such as; complex anatomy including short neck, inability to hyper-extend the neck, impalpable trachea, and obesity etc.[9]

The location and connection of all anatomical structures can be quickly distinguished by using a linear array probe via 2D ultrasound. These anatomical structures may include, jugular & carotid vessels, thyroid gland, tracheal rings, cricoid & thyroid cartilages etc. Moreover, spectral or color Doppler can be utilized to observe aberrant vascular landmarks. Also, real-time ultrasound can help in distinguishing the right point where the puncture should be made, whereas if the probe is rotated at a 90-degree angle, it can help in the visualization of the needle tip, assisting it to move through the midline.[10]

The study was conducted to compare the extent of procedure efficacy and postoperative complications of ultrasound-guided percutaneous dilatational tracheostomy with a conventional bronchoscopy guided percutaneous dilatational tracheostomy, especially among obese ICU patients (Body mass index of ≥30 kg/m^2).

Methodology

It was a prospective, randomized & comparative study, carried out in the critical care department of Services Hospital, Lahore. The duration of the study was one year; i.e. from April 2020 to April 2021 where all patients were enrolled in the study who fulfilled the criteria for tracheostomy. Fifty-two adult patients (M/24,F/28), who were intubated and requiring long-term airway and ventilatory support, were enrolled in the study. These fifty-two ICU patients were randomly assigned into 2 groups (A and B). In group A, there was a total of 25 patients (10 normal weight/overweight persons with a BMI of ≤29.9 kg/m^2 and 15 obese persons with BMI of ≥30 kg/m^2) whereas, in group B, there was a total of 27 patients (13 normal weight/overweight persons with BMI of ≤29.9 kg/m^2 and 14 obese persons with BMI of ≥30 kg/m2). Group A patients were supposed to undergo ultrasound-guided percutaneous dilatational tracheostomy (PDT) and group B patients were assigned to conventional bronchoscopy guided percutaneous dilatational tracheostomy procedure. Patients having any of the following medical complications were disqualified from the study: severe sepsis/shock, striking dysautonomia, marked hypoxemia (FiO2 >60%), thrombocytopenia >50000, coagulopathies/DIC,

local neck infections, history of neck surgeries or tracheostomy, and abnormalities in neck, trachea, or spine structures etc. Eligibility criteria to recruit patients included those who failed three or more standardized weaning trials up to 14 days of elective ventilation. Similarly, patients whose duration of ventilation was expected to be prolonged (more than 2 weeks) due to the nature of their disease, for example, GBS, cervical spine injury, traumatic brain injury, persistent vegetative state, generalized tetanus, myopathies, etc. and those who had a very difficult trans-laryngeal endotracheal intubation due to variety of transient medical conditions including tetanus, poisoning, idiopathic laryngeal edema, infections, tumors etc. were also included.

For patients in both groups, Ciaglia's technique (Blue Rhino; Cook Critical Care; Bloomington. IN) of PDT was applied. After receiving an informed consent from families of patients (elaborating the advantages and potential complications of procedure) bronchoscopy guided and ultrasound guided PDT were conducted at bedside with local anesthetic application, sedation with systemic analgesia, in respective groups. A Sonosite M-Turbo ultrasound machine with linear transducer (HFL38x, 13-6MHZ) was used among group A, whereas an Olympus Video-bronchoscope 2C-260 was used for group B patients.

No transportation was required and the procedure was carried out at bedside in MICU settings without the assistance of an anesthetist. To both groups, ventilation (leak proof and assured) was continued through ETT # 08 with parameters individually set according to patient's disease, body weight and disease nature etc. All patients were placed in supine position with head hyperextended by positioning a pillow-roll beneath the shoulders. Among group A, a sterile sleeve for ultra-sound probe was used during the procedure whereas, for group B patients, olympus fiberoptic bronchoscope was inserted under sterile conditions. Tramadol in an average dose ranging 50-100mg or Nalbuphine 5-10mg were used intravenously as an analgesic and propofol boluses were used in sedation. Moreover, a bolus of 0.4-0.5 mg/kg of atracurium was used to relax the muscles. Patients were kept "Nil per oral" 6 hours prior to procedure and the operating site was disinfected with a povidone-iodine solution, and 2% lignocaine solution was used later on as a local anesthetic.

Later, the Ciaglia's kit (Blue Rhino; Cook Critical Care; Bloomington. IN) cannula was passed between the 3rd and 4th tracheal rings under the real time ultrasonography (Group A) which not only helped to identify the desired tracheal interspace but guided the needle tip and guidewire inside the trachea. Similarly, tracheal spaces for cannulation (Group B) were confirmed through transillumination of surgical site by bronchoscope. Movement of cannula/needle (by avoiding puncture to posterior tracheal wall) and guidewire were continuously viewed and guided during the procedure. For both groups, after setting the guidewire inside the trachea, 1cm linear incision was given and 8-F dilator was used for the dilatation of track. Later, a blue rhino dilator was used to complete dilatation for tracheostomy tube (TT) insertion. After assuring TT position in trachea (ultrasonologically in group A and bronchoscopically in group B), cuff was inflated upto 16-24mm.Hg pressure and ventilation ensued through it.

A roentgenogram of lungs was ordered to all patients to rule out surgical emphysema, to see the position of tracheostomy tube tip from tracheal carina (To rule out right sided cannulation). $ETCO_2$ levels, body temperature, SPO_2 and ECG of all patients were continuously monitored throughout the procedure.

Data including the age, gender, operation time, lowest intraprocedural SPO_2, lowest intraprocedural BP, intraprocedural hemorrhage, tracheal ring fracture, single/multiple punctures, subcutaneous emphysema, pneumothorax, surgical conversion of procedure, a new lung infiltrate and death were documented.

Complications of the procedure were recorded as below: Hypotension as systolic BP under 90mmHg. Hypoxemia as SaO_2 below 90%. Bleeding was graded: Mild; 25 to 100mls, moderate; 100 to 250mls and severe as more than 250mls.

The approval was obtained from Department of Pulmonology, Services Institute of Medical Sciences & Services Hospital, Lahore.

Results

In our study, a total of 52 percutaneous dilatational tracheostomies were carried out; 25 under real time ultrasound-guidance and 27 through bronchoscopic visualization. Out of 52, 28 were females and 24 male patients with mean age 48±13 in group A and 47±14 in group B. Operative time was comparatively less in group A (8-10mins) if compared with group B (12-15mins).

Intraoperative mild hemorrhage occurred only in 1/15 (6.6%) patient in group A and among 3/14 (21.4%) patients in group B. In group A out of total 25 patients, 14(56%) required single tracheal puncture for cannulation and 11 (44%) had multiple punctures. Whereas, in group B 11 (41%) required single and 16 (59%) required multiple punctures. Complications including tracheal ring fracture,

transient hypoxemia and hypotension, loss of airway, difficult to ventilate the patient and cardiac arrhythmias didn't occur in both of groups.

Intraoperative hemorrhage occurred only among obese patients (from both of the groups) in our case series.

No postoperative complications were noted in both groups including pneumothorax, sub-cutaneous emphysema hemorrhage and a new lung infiltrate within 48hours of tracheostomy. There were no surgical conversions of procedure or deaths noted among both of groups.

The results obtained from patients of group A and group B are shown in Table.

Table: Patient's characteristics.

1.	Male/Female = 52	(M/24, F/28) = 52
2.	Age, yr, Mean ± SD	A(Group) 48±13, B (Group) 47±14
3.	Operation Time	A(Group) 8-10mins, B(Group) 12-15mins
4	*Intra-operative Complications*	
a.	Hemorrhage (Mild 25 to 100mls)	A(Group) 1, B(Group) 3
b.	Tracheal Ring Fracture	A(Group) 0, B(Group) 0
c.	Transient Hypotension/ BP < 90 systolic	A(Group) 0, B(Group) 0
d.	Transient Hypoxemia/SpO2 drop ≤ 90%	A(Group) 0, B(Group) 0
e.	Single/Multiple (two or more) puncture(s)	A(Group) 14/11, B(Group) 11/16
f.	Difficult to ventilate a patient.	A(Group) 0, B(Group) 0
g.	Loss of airway	A(Group) 0, B(Group) 0
h.	Cardiac arrhythmias	A(Group) 0, B(Group) 0
5.	*Postoperative Complications*	
a.	Surgical conversion of procedure	A(Group) 0, B(Group) 0
b.	Pneumothorax	A(Group) 0, B(Group) 0
c.	Subcutaneous emphysema	A(Group) 0, B(Group) 0
d.	Hemorrhage	A(Group) 0, B(Group) 0
e.	A new Lung Infiltrate within 48hours of tracheostomy	A(Group) 0, B(Group) 0
f.	Death	A(Group) 0, B(Group) 0

Discussion

PDT has many advantages over the conventional surgical approach. It is simple, quick to learn, less expensive and easy to perform at bedside without moving the patient outside the ICU premises.[11] This is mostly needed in cases where the patient's condition does not allow transportation outside the unit or technical/logistic limitations do not support to displace a patient. During the past few years, rate of performing the percutaneous dilatational tracheostomy has significantly been escalated in ICU facilities.[12]

The aim of our case series was to determine the safety of percutaneous dilatational tracheostomy with the help of real time ultrasound guidance with direct visualization of the needle & guidewire path way which has a potential advantage of ability to place the tracheostomy tube consistently below the first tracheal ring especially among obese and critical ICU patients. Placement of tracheal tube above the first tracheal ring may increase the risk of late sub-glottic cicatrization and stenosis.[13] Moreover, the use of real time ultrasound guidance for percutaneous dilatational tracheostomy has several advantages including low cost, portability of machine, easy handling and least invasiveness.

Bronchoscopic guided percutaneous dilatational tracheostomy ensures the accurate placement of needle and guide wire inside the trachea however it has the disadvantages of inability to distinguish surrounding anatomic sites of trachea, which can cause accidental injuries to structures and complications secondly puncturing needle can hit the bronchoscope tip leading to equipment damage and thirdly, increased risks of sub-cutaneous emphysema despite direct visualization of needle insertion into the trachea during the procedure.[14]

In our study of 52 patients, in whom percutaneous dilatational tracheostomy was inserted in the setting of ICU with the help of both ultrasound and bronchoscopic guidance, the former modality was found to be as efficacious as the latter one, but with low rates of intra-procedural complications in comparison. Several studies have emphasized the value of pre-procedure ultrasound of neck by an expert to the reduce the incidence of complications,[15] but despite the presence of obesity, sub-optimal palpable neck anatomy or cervical spine limitations did not appear to be a barrier to the performance of per-procedural (real time) ultrasound guided percutaneous dilatational tracheostomy. None of our patients had prior tracheostomy done and previous studies have shown that percutaneous dilatational tracheostomy should be automatically contraindicated in these groups of patients.[16] Operation time (Procedure time) was comparatively less, 8-10mins in ultrasound guided group A whereas it remained 12-15mins among group B, bronchoscopic guided patients. In our opinion it was related to ease of performance of procedure by a single operator using ultrasound machine for guiding the needle into trachea.

Two different intra-operative complications were noted only, among obese patients from both groups including minor hemorrhage and multiple punctures for tracheal cannulation. Out of 15 obese patients in group A only 1 (6.6%), and out of 14 obese patients in group B 3 (21.4%) minor

hemorrhages which favors the superiority of ultrasound guidance for PDT. Similarly, 11/15(73%) obese patients from group A had more on one attempts of tracheal cannulation where as in group B, all of 14/14(100%) obese patients had more than one tracheal cannulation attempts.

Parli Raghavan et al [17] compared the safety of percutaneous dilatational tracheostomy among obese patients using bronchoscopy and ultrasound guidance. Out of 74 patients admitted in intensive care unit with variety of medical and surgical problems including stroke, COPD exacerbation, ARDS, seizures and trauma, 26 were obese with BMI 32-38. In terms of complications 8 tracheal cuff punctures in bronchoscopy guided group (BGG) vs nil in ultrasound guided group (UGG), number of tracheal puncture attempts; BGG 4 against 0 in UGG, intraprocedural desaturation; BGG 4 and UGG nil and Bleeding; BGG 12, UGG nil, which are comparable to our study where safety profile of ultrasound guided procedure was better if compared with ultrasound guided procedures. Procedure time was 18 minutes for BGG and 12 minutes for UGG which is similar to the procedure time results in our study.

Vi AM Dinh et al. [18] emphasized the safety of sonographic guided percutaneous tracheostomy procedure where they have found an initial midline introducer needle puncture rate around 72.7% in the sonography group compared to 8.3% in the land mark group. The mean number of introducer needle punctures was significantly lower in the sonography group compared to landmark group (1.4 vs 2.6). And the total tracheostomy time was 11.4 minutes in sonography group vs 15.3 minutes in landmark group. Once again, the results here are comparable to our study and conclusive about the safety of ultrasound guided over bronchoscopy guided procedures.

Percutaneous dilatational tracheostomy performed under ultrasound guidance is safer and quicker for critically ill, obese ICU patients if compared with PDT under bronchoscopic guidance.

We recommend a routine use of real time ultra-sonography during percutaneous tracheostomy especially among obese ICU patients to minimize the procedure related complications and procedure time.

Conflict of interest: None declared.

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