THE PERCUTANEOUS DILATATIONAL TRACHEOSTOMY
IN THE INTENSIVE CARE UNIT – OUR EXPERIENCE

PERKUTANA DILATACIONA TRAHEOSTOMIJA
U JEDINICI INTENZIVNE TERAPIJE – NAŠE ISKUSTVO

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Summary

Percutaneous tracheostomy is a commonly carried out procedure in patients in the Intensive Care Unit. Percutaneous dilatational tracheostomy consists of the introduction of a tracheal cannula from the front of the neck, through blunt dissection of the pretracheal tissues, using a guide by Seldinger technique. When percutaneous dilatational tracheostomy procedure was introduced in routine clinical practice in the Clinical Center of Vojvodina, procedural protocol was established. This Protocol includes: 1. indications, contraindications and timing for percutaneous dilatational tracheostomy, 2. assessment of the patient, 3. preparation of the patient and equipment, 4. procedure description, 5. potential complications and complication management. At our institution percutaneous dilatational tracheostomy is performed on an individual patient basis assessment within 5-7 days following translaryngeal intubation. Routinely the platelet count, activated prothrombin time and prothrombin time are checked. The patient’s neck is assessed clinically and by the use of fiberoptic bronchoscope and ultrasound. At our institution we use the modified Ciaglia technique of the percutaneous dilatational tracheostomy—Ciaglia Single Dilator method with the TRACOE® expire Set vario which includes spiral reinforced tracheal cannula. At the end of procedure fiberoptic evaluation of the tracheobronchial tree is made and chest X-ray is done. Percutaneous dilatational tracheostomy is a simple, safe, and effective procedure performed in the Intensive Care Unit. It is the preferred technique of airway management in the Intensive Care Units in the patients requiring prolonged mechanical ventilation, tracheobronchial hygiene and weaning from mechanical ventilation.

Key words: Intubation, Intratracheal; Tracheostomy; Critical Illness; Intensive Care Units; Airway Management; Bronchoscopy; Ultrasonography; Respiration, Artificial

Introduction

Percutaneous tracheostomy is a commonly carried out procedure in patients at the Intensive Care Unit (ICU) in order to maintain their airway, to remove excessive airway secretions and to enable mechanical ventilation to be gradually withdrawn. It is performed by anaesthetists and intensive care physicians as a bedside procedure [1, 2]. Percutaneous dilatational tracheostomy (PDT) consists of the...
introduction of a tracheal cannula from the front of the neck, through blunt dissection of the pretracheal tissues, using a guide by Seldinger technique [1,3].

In the Clinical Center of Vojvodina we perform PDT with one of the commercially available sets, under endoscopic and ultrasound guidance.

**History of the Percutaneous Dilatational Tracheostomy**

The first alternative to open surgical technique of tracheostomy was described by Shelden and colleagues [4]. Until now, several techniques of percutaneous tracheostomy have been described. Some of them belong to the history of medicine.

In 1985 Ciaglia and colleagues performed percutaneous tracheostomy using a guide wire (Seldinger technique) and multiple dilators [4]. Few years later, Schachner designed special percutaneous tracheostomy tool which slid over the guidewire into the trachea. The intercartilaginous space was enlarged by squeezing the handles of this tool, securing the placement of cannula into the trachea [4]. A simple percutaneous tracheostomy technique with the guidewire and modified Kelly's forceps was published by Griggs in 1990 [4]. Fantoni described tracheostomy technique through translaryngeal approach in 1997 [5]. Later, Ciaglia modified his own PDT technique: the novel technique include the use of single tapered tracheal dilator instead of multiple dilators use [4]. Frova invented a single-step technique with screw-like dilator. Dilatation is performed by clockwise rotation of the screw, until it reaches the trachea [4]. Zgoda and colleagues reported on balloon dilatational technique of PDT in 2005 [4].

**Percutaneous Dilatational Tracheostomy in the Clinical Center of Vojvodina**

PDT procedure was first introduced in routine clinical practice in the Clinical Center of Vojvodina on March 8th, 2017, according to PDT Protocol which was established at the same time. Since then, more than 200 PDT have been performed at our institution. The Protocol includes: 1. indications, contraindications and timing for PDT, 2. assessment of the patient, 3. preparation of the patient and equipment, 4. procedure description, 5. potential complications and complication management.

**Indications, contraindications and timing for PDT**

The decision to perform a PDT in the ICU patients is made by an anaesthesiologist-intensivist at our institution. It is based on indications, contraindications and timing as well as the assessment of the patient.

The general indications of PDT are: 1. the need for prolonged ventilatory support (up to 24% patients in the ICU) [4], 2. compromised pulmonary and/or tracheobronchial toilet [6], 3. adjunct to weaning from mechanical ventilation [6], 4. airway protection and prevention of the pulmonary aspiration in a patient with poor protective airway reflexes (severe alteration of the conscious, neuromuscular diseases, diseases of the central nervous system) [2], 5. upper airway obstruction [7], 6. head and neck surgery or trauma [8].

Contraindications of PDT can be absolute and relative. Absolute contraindications of PDT include: 1. pediatric patients (below 10 years of age), 2. local infection of the neck tissues, 3. unstable cervical spine injuries, 4. extreme coagulopathies, 5. inexperienced anaesthesiologist – intensivist [9,10].

Relative contraindications include: 1. enlarged thyroid gland, 2. obvious pulsating blood vessel under the skin at the operation site, 3. gross distortion of the neck anatomy (short neck, obesity, local malignancy, tracheal deviation, limited neck extension), 4. burns of the skin at and near the operation site, 5. need for high positive end-expiratory pressure (PEEP) of more than 10 cmH₂O or high level of inspiratory oxygen concentration (FiO₂ >70%), 6. previous neck injury or previous tracheostomy, 7. high positioned innominate artery, 8. cervical radiotherapy four weeks before performing PDT, 9. controlled local infection of the neck [9–12].

The number of relative contraindications is decreased when PDT is performed by a trained and experienced anesthesiologist-intensivist and when PDT is performed under the control of fiberoptic bronchoscope (FOB) in conjunction with ultrasound (US) [8].

The timing of insertion of the PDT in the ICU still remains a debate topic. There is no consensus in literature what insertion time of tracheal cannula is considered early or late. Prolonged translaryngeal intubation is associated with mucosal damage to the larynx and vocal cords. If endotracheal tube is removed within 3 – 7 days, complete healing of laryngeal injury is possible [13]. If translaryngeal intubation is prolonged, for more than one week, laryngeal injury progresses with scar formation and functional abnormality in voice [14]. Although complications of the PDT are rare, some of them may be serious [8,9]. The decision involves a comparison of the risks and benefits of performing a PDT compared with the risks and benefits of continued endotracheal intubation [15]. According to the results of The TracMan Randomized Trial, in which 909 patients were included, early tracheostomy within 4 days versus late within 10 days or more after admission into ICU was not associated with an improvement in 30-day mortality or other important secondary outcomes. There were no significant differences in use of the antibiotics, ventilator associated pneumonia (VAP) or ICU length of stay. The authors found a moderate reduction in sedative use [16]. Novel Danish Guidelines for PDT in the ICU suggest that optimal timing of tracheostomy insertion should be determined on an individual patient basis (2B) [9].

At our institution, PDT is performed on an individual patient basis assessment, within 5–7 days following translaryngeal intubation.

**Assessment of the Patient**

The careful patient assessment is performed before PDT. The platelet count, activated prothrombin time
(aPTT) and prothrombin time (PT) are routinely checked. If the platelet count is less than 50 x 10^9 cells/l and if aPTT and/or PT are more than 1.5 times the reference range, PDT is not performed. However, Kluge and colleagues have concluded that percutaneous tracheostomy is safe even in the patients with severe thrombocytopenia if the procedure is performed by experienced personnel, with bronchoscopic guidance and if platelets are administered before intervention [17]. When assessing the patient's neck, we look for anatomical features that suggest that the PDT may be difficult or that we should perform surgical tracheostomy. Low neck extension, neck oedema, gross overweight, and goitre make identification of the local landmarks at larynx and trachea more difficult [18].

**Preparation of the Patient and Equipment**

In order to prevent aspiration of the stomach contents into the airway according to our Protocol enteral nutrition is stopped 2 hours before the planned time of PDT. The stomach content is emptied by the active suction of the nasogastric tube just before the procedure.

During the PDT procedure continuous electrocardiography monitoring, pulse oxymetry, and monitoring of the arterial blood pressure (non-invasive and/or invasive) are used.

In case of accidental extubation of the patient and airway emergencies during the procedure, the Difficult Airway Trolley is always readily available at the bedside. All patients are preoxygenated with 100% oxygen. The patients are mechanically ventilated. The frequency, Tidal volume and maximum airway pressure on the ventilator are adjusted to compensate for the air leak during the procedure. Inspiratory fraction of the oxygen (FiO2) is kept on 1.0. PDT is carried out under general anaesthesia, or under adequate analgesia and sedation, with muscle relaxation at our institution. When adequate sedation and muscle relaxation of the patient is achieved, the suction of secretions from the tracheobronchial tree is performed. Proper position and adequate extension of the neck is achieved by placing a firm roll under the patient's shoulders. Anatomical landmarks are assessed clinically and by the use of FOB and US.

**Clinical Assessment of Anatomical Landmarks**

When palpating from the chin downwards in the midline, the hyoid bone can be easily felt [19]. The thyroid cartilage is the next palpated anatomical structure in the midline of the anterior neck. Its most prominent part, the laryngeal prominence (the Adam's apple), is more prominent in men than in women and children. Cricotyroid membrane (CTM) is followed by laryngeal prominence. CTM has a trap-ezoid shape with the width ranging from 27 to 32 mm and the height ranging from of 5 to 12 mm [20].

The cricoid cartilage is the strongest cartilage of the larynx. It lies directly below the thyroid cartilage and it represents the anatomic lower limit of the larynx. Since the cricoid cartilage is the only complete cartilaginous ring in the airway (shaped like signet ring), it has the important role to support the larynx [21]. The transverse cricothyroid artery is placed at the upper half of the CTM. Due to such position of the transverse cricothyroid artery, it might be easily injured. When it is injured, massive hemorrhage could occur, since the transverse cricothyroid artery is a branch of the superior thyroid artery [22]. PDT performed just below the cricoid cartilage may later lead to the development of subglottic tracheal stenosis [23]. Because of all above mentioned anatomical features, PDT should not be performed right below the cricoid cartilage or through the cricothyroid membrane.

The trachea begins at the cricoid cartilage and ends at the level of sternal angle by dividing into the right and left principal bronchi. In an adult, the trachea is 11 to12 cm long and its internal diameter is 12 – 17 mm. It contains 15 to 20 C-shaped cartilaginous incomplete rings, which are 2 – 6 mm high. The distance between two cartilages is 2 – 3 mm. Posteriorly, trachea consists of a membrane of smooth muscle and fibroelastic tissue joining the ends of the cartilages. Each tracheal ring is anteriorly individually connected by an annular ligament. The trachea goes to the depth of 2.0 to 2.5 cm from the skin surface. The depth of the trachea increases on its moving into thorax, especially in older people. At the level of the second or third tracheal ring the trachea is covered by the isthmus of the thyroid gland. Therefore, the safest place to perform the PDT is under the third tracheal ring because the puncture of the isthmus of the thyroid gland is avoided [23]. A proximal placement of the tracheal cannula increases the risk of tracheal stenosis. A more distal placement of the tracheal cannula increases the risk of erosion of the great vessels in the mediastinum [9].

**The Use of Fiberoptic Bronchoscope**

The first important role played by FOB is discovering and evaluation of possible injuries involving larynx and trachea which might be present before tracheostomy, as a consequence of translaryngeal intubation [26]. Secondly, according to our experience, better suction of secretions from the tracheobronchial tree is achieved by means of the FOB. In order to provide real-time visualisation of the carina, tracheal rings and carina, and in order to confirm identification of the correct puncture site at the front of the neck for PDT cannula placement, FOB is used at our Institute. Transillumination of neck soft tissues allows us to recognize the front of the neck vessels running across the neck midline and maybe to change the puncture site in order to avoid bleeding complications. The successful introduction of the needle into the trachea under direct visualisation minimize the risk of posterior tracheal wall injury [27]. The FOB is performed to control the guidewire progression, dilatation of tracheal stoma and correct placement of tracheostomy cannula. At the end of PDT procedure with FOB the tracheal cannula position is checked, a possible clot
from tracheobronchial tree is removed and the occlusion or herniation of the cannula cuff is noticed.

The Use of Ultrasound

The use of the ultrasound (US) as a possible adjunct to the PDT is suggested by current guidelines [9, 28]. The advantage of the preprocedural US use are as follows: 1. defining the relevant anatomy and identifying tracheal midline, 2. identifying aberrant blood vessels and avoiding immediate vascular complications, 3. estimating trachea depth from the skin surface and tracheal diameter (this helps in proper selection of tracheostomy tube size and length especially in patients with an increased pre-tracheal soft tissue diameter), 4. ensuring accurate placement of needle into the trachea. To summarize, the preprocedural use of the US may help to identify patients unsuitable for PDT, to decrease the number of immediate complications, and shorten the procedure time [9, 28, 29].

Procedure Description

At our institution we use the modified Ciaglia technique of the PDT—Ciaglia Single Dilatator method with the TRACOE® expexc Set vario which includes spiral reinforced tracheal cannula (TRACOE medical GmbH, Nieder-Olm, Germany). The set consists of a scalpel, 10 ml syringe, 14 G puncture needle with tfelon catheter, Seldinger guide wire made of kink resistant nitinol with inserter, 14 Ch/Fr short dilator, guiding catheter with safety stop, TRACOE expexc dilator with hydrophilic coating which slides easily after moistening, 4 compresses and spiral-reinforced, with adjustable neck flange, cuff and atraumatic insertion system tracheostomy cannula. Preparation of the PDT set consists of 1. choosing the size of the tracheal cannula which is done according to the clinical judgement; 2. tracheal cannula cuff leakage test; 3. lubrication of the tracheal cannula cuff; 4. filling the syringe with 5 ml of saline; 5. preparation of the dilation set: the hydrophilic coating of the dilatator is activated by means of a saline solution and kept moist until used.

When the anatomical landmarks are identified and the proper place of PDT insertion is marked, an intensivist prepares the operation site. The operation site is cleansed with coloured antiseptic 2-propanol-biphenyl-2-ol solution (Kodan® tinture forte coloured, Schülke&Meyer Gmb, Norderstedt, Germany) and 2 minutes contact time are waited. After the operation site is properly cleaned, sterile covering of the operating field is carried out. The bronchoscopy swivel adapter with a snug FOB diaphragm opening is placed by the anaesthesiologist in charge of airway management. The use of bronchoscopy swivel adapter allow us mechanical ventilation of the patient without air leakage. Bronchoscopy is introduced just to the tip of the endotracheal tube, so that anatomical structures of the trachea could be visualized. The fixation strips of the endotracheal tube are united and the cuff of the endotracheal tube is deflated. The endotracheal tube is carefully withdrawn together with the FOB until transillumination is obtained at the selected operation site at the front of the neck. Then the cuff of the endotracheal tube is carefully reinflated to the original volume. In order to prevent any damage to the FOB that could be caused by the intensivist’s needle during the procedure of the PDT, it is very important to keep the flexible tip of the FOB just to the tip of the endotracheal tube.

Before puncturing the anterior tracheal wall, some authors advocate infiltration of the local anaesthetic containing adrenaline at the chosen level of the front of the neck in order to reduce bleeding from the skin to the trachea [9, 30]. The local anaesthetic containing adrenaline at the place of percutaneous cannula insertion is not infiltrated by an intensivist at our institution because horizontal skin incision is minimal and blunt dissection of the subcutaneous and deeper tissues according to our protocol is not anticipated, so thus bleeding possibility is minimal.

Anterior tracheal wall is punctured with a 14-gauge needle with teflon catheter right on the central line under the FOB. The hollow needle is pushed forward until the tracheal entry of the cannula is confirmed by aspiration of air into the saline-filled syringe and by direct bronchoscopic visualization. The puncture needle is removed but the teflon catheter remains in situ. The Seldinger “J” tip guidewire robust against buckling is inserted into the teflon catheter and moved forward and downwards into the trachea. The teflon catheter is removed and horizontal skin incision is made using scalpel from both sides of the guidewire. The 14-French initial dilator is advanced over the Seldinger guide wire in order to start a tracheal stoma formation. This is called predilation. When performing predilation, care should be taken to see that the short dilatator is tilted cranially to ensure safe dilation. The second reason why the short dilator should be tilted cranially is to prevent puncture of the posterior tracheal wall. Following predilation, the short dilator is removed and the Seldinger guide wire stays in situ. A moisturized hydrophilic dilator slides easily over the guide wire and advances slowly into the trachea. Attention has to be paid on the proximal mark of the Seldinger guide wire, which must be visible at the proximal end of the white guiding catheter. Dilation is performed by moving the dilation unit forward several times until 38 Fr is reached which should become visible with FOB to the anaesthesiologist in charge of airway management. Dilation with moving dilation unit forward until 38 Fr is eunough to place the cannula size 8 (8.0 internal diameter). During the process of dilation, care should be taken to ensure that the positions of the guiding catheter and the Seldinger guidewire remain constant in relation to the dilator. The dilator is removed and Seldinger guidewire stil remains in situ. The mark at the proximal end of the Seldinger guidewire must be visible. The tracheal cannula is pushed forward under the FOB view through the Seldinger guidewire. When the neck flange has reached the skin level, the inserter, the guiding catheter and Seldinger guide wire are removed all in one action. On removal, all of three components (the inserter, the
guiding catheter and Seldinger guidewire) are checked in order to ensure that all of them are complete. The cuff is inflated and the ventilator to the tracheal cannula is attached. Tracheostomy cannula cuff pressure is maintained in the range of 20–25 mmHg. At the end of procedure, FOB is placed by the anaesthesiologist in charge of airway management through the tracheal cannula in order to ensure that distance from the tip of the tracheostomy cannula and the tracheal carina is sufficient. FOB is also used to evaluate the respiratory tract below the tracheal cannula and to remove possible blood clots from the tracheobronchial tree. The tracheal cannula is secured by tapes and the proper dressing is placed at the skin wound site. Chest X-ray is done at the end of the PDT intervention.

Complications of the PDT

Complications following PDT can be categorized as immediate, early and late [8, 9]. Immediate complications include: bleeding, hypoxia caused by loss of the airway, fracture of the tracheal cartilage, surgical emphysema, injury of the posterior tracheal wall, paratracheal placement of the tracheal cannula, pneumothorax, laryngeal nerve damage [8, 9, 31, 32]. Bleeding, hypoxia, emphysema, pneumothorax, blockage or/and displacement of the tracheal cannula, local infection can be considered as early complications [32, 33]. Late complications include: bleeding, hypoxia, blockage or/and displacement of the tracheal cannula, local infections, voice changes, tracheal stenosis, persistent stoma, dysphagia, disfiguring scar, and tracheomalacia [34].

The frequency of most reported complications is inversely proportional to the experience of the anaesthesiologist/intensivist [8].

Conclusion

PDT is a simple, safe, and effective procedure performed in the ICU. In the hands of a skilled anaesthesiologist and intensivist it is the preferred technique of airway management in the ICU in patients requiring prolonged mechanical ventilation, tracheobronchial hygiene and weaning from mechanical ventilation. Proper selection of patient and the use of procedural adjuncts decrease the complication and failure rates.

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