Intracranial Pressure Monitoring During Percutaneous Tracheostomy "Percutwist" in Critically Ill Neurosurgery Patients

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BACKGROUND: Tracheostomy is commonly required as part of the management of patients with severe brain damage. Percutaneous dilation tracheostomy is increasingly used in intensive care unit as an alternative to standard surgical tracheostomy. However, this procedure carries the risk of neurological complications, particularly in patients with intracranial hypertension. In this study, we sought to quantify the effects of Percutwist® tracheostomy (Rusch-Teleflex Medical) on intracranial pressure (ICP), cerebral perfusion pressure (CPP), arterial CO_2 tension ($Paco_2$), and arterial O_2 tension (Pao_2), in 65 consecutive critically ill patients admitted to the neurosurgical intensive care unit, undergoing bedside percutaneous tracheostomy.

METHODS: Sixty-five patients (29 men, 36 women, mean age 43 yr, 7 ± 10.6) Glasgow Coma Scale ≤8, requiring long-term ventilatory support with a stable ICP ≤20 mm Hg were included. Elective percutaneous tracheostomies were performed at the bedside under endoscopic fiberoptic control. Intraoperative monitoring included continuous: electrocardiogram, Spo_2, invasive arterial blood pressure, ICP, CPP = mean arterial blood pressure-ICP). Episodes of ICP increment above 20 mm Hg or CPP decrease below 60 mm Hg (lasting more than 3 min) were recorded; hypoxia was defined as Pao_2 below 90 mm Hg, hypercarbia as $Paco_2$ more than 40 mm Hg.

RESULTS: Eighteen episodes of intracranial hypertension were recorded in 11 patients. No statistically significant modification of monitored variables was recorded, although the transient ICP increase was very close to statistical significance ($P = 0.051$). No episodes of CPP reduction below 60 mm Hg occurred. Six percent of patients developed hypercarbia.

CONCLUSIONS: Percutwist tracheostomy is a single-step method which allows for effective ventilation during the procedure, thus reducing the risk of hypercarbia and development of intracranial hypertension. The technique did not cause secondary pathophysiological insult and could be considered safe in a selected population of brain-injured patients.

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Percutaneous dilatational tracheostomy (PDT) is a safe procedure for airway management in critically ill patients requiring long-term ventilatory support.[1,2]

In neurologically critically ill patients, tracheostomy carries a high risk of neurologic deterioration due to potential disturbances of neurophysiological, hemodynamic, and respiratory variables.[3,4] In fact, the pressure applied to the neck during the dilation maneuver can reduce jugular venous outflow, and the use of fiberoptic endoscopy, tube suctioning, and multiple dilators can lead to desaturation, hypoxia or hypercarbia,[5] which are deleterious in patients with impaired cerebral compensatory mechanisms. Several studies have compared different techniques of tracheostomy in terms of complications, feasibility, and long-term sequelae.[6–9] One study reported no major bleeding or complications in 90 intensive care unit (ICU) patients who underwent tracheostomy using the single-step Percutwist method.[10]

Few studies[11,12] have analyzed the impact of different tracheostomies on cerebral variables and there are no studies regarding intracranial pressure (ICP) modifications during the Percutwist technique. The aim of this study was to quantify the incidence of insults on cerebral (ICP/cerebral perfusion pressure [CPP]) and respiratory variables (Pao_2/$Paco_2$) during Percutwist tracheostomy in 65 consecutive critically ill patients admitted to the neurosurgical ICU (NSICU).

METHODS

After written informed consent was obtained from patient's relatives, data of patients requiring tracheostomy and monitored for ICP were collected and IRB

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Table 1. Conditions Leading to NSICU Admission

	Trauma brain injury	SAH	Hematoma	Meningioma
No. of patients	17	28	8	12
Mean age (yr)	39 ± 12.3	45 ± 10	43 ± 9.2	47 ± 9.2
Intraventricular catheter	10	23	0	8
Intraparenchimal catheter	7	5	8	4

NSICU = neurosurgical intensive care unit; SAH = subarachnoid hemorrhage.

approval was obtained for publication. Indications for tracheostomy were protection of airways on neurological grounds and planned prolonged mechanical ventilatory support for ≥14 days, given that ICP remained stable in the previous 2 days.

Absolute contraindications were: 1) unstable ICP, defined as ICP more than 20 mm Hg lasting more than 5 min and requiring additional active treatment, occurring within the 24 h before inclusion in the study; 2) emergency conditions; 3) difficult intubation or identification of anatomic landmarks; 4) coagulation disorders; 5) extensive thyroid enlargement or preexisting tracheomalacia; and 6) unstable cervical spine injury. The technique was described by Frova and Quintel[13,14] and uses a dilator set for percutaneous controlled dilative tracheostomy (Percutwist Rusch–France; supplier Teleflex Medical S.r.l. via Torino, 5-20039 Varedo, Milano, Italy). The procedures were performed by senior consultants and all patients were premedicated with atropine 0.01 mg/kg and IV infusion of 15 mL/kg of crystalloid solution was started. Induction of general IV anesthesia was performed with propofol 1–2 mg/kg, fentanyl 3–5 μg/kg, and vecuronium 0.08 mg/kg. Supplemental IV boluses of fentanyl (50–100 μg) were administered when clinically indicated. Depth of anesthesia was assessed clinically: significant increases in heart rate or mean arterial blood pressure (MAP) or any autonomic signs of inadequate anesthesia were monitored and treated accordingly. All patients were positioned with the head tilted up at 20°, without hyperextension of the neck. A 5 mm size Olympus flexible bronchoscope was inserted intratracheally to confirm guidewire placement. Mechanical ventilation with an inspired concentration of 100% oxygen was adjusted to obtain a satisfactory end-tidal CO_2 volume. In our male population, the inner diameter of the tracheostomy tube was 8 or 9 mm and in the female population it was 7 or 8 mm. Patients were continuously monitored with electrocardiogram, arterial oxyhemoglobin saturation (Spo_2), MAP through an intraarterial catheter, ICP through an intraventricular or parenchymal (Becker-bolt) catheter zeroed at the level of the external acoustic meatus and CPP, as a derivate value (CPP = MAP−ICP).

The ICP and MAP were monitored continuously and averaged over 1 min. Mean values of MAP, ICP, CPP, Pao_2, $Paco_2$ were obtained during the main phases into which the entire procedure was divided: 1) baseline, before inducing anesthesia, 2) endotracheal tube (ETT) repositioning and/or replacement, 3) dilation maneuver, 4) cannula placement, and 5) end of procedure.

Episodes of ICP increment above 20 mm Hg or CPP decrease below 60 mm Hg (lasting more than 3 min) were recorded. Hypoxia was defined as Pao_2 below 90 mm Hg and hypercarbia as $Paco_2$ more than 40 mm Hg. Any ICP peak was treated with a 25–50 mg IV bolus of sodium-thiopental and/or withdrawal of cerebrospinal fluid (when possible).

According to the Frova-Quintel classification,[13] intraoperative bleeding was classified as absent or minimal (none or minimal bleeding requiring no intervention), medium (need for special wound dressing or vasoconstrictive infiltration), or serious (requiring surgical intervention).

All continuous variables are expressed as mean ± SD unless otherwise specified. Statistical testing was conducted using Friedman repeated measures analysis of variance on ranks; when appropriate, all pairwise multiple comparisons were made with Holm-Sidak method. A value of $P < 0.05$ was considered significant. The package used was Sigma Stat for Windows.

RESULTS

From January 2004 to July 2007, 65 bedside procedures were performed in the NSICU of the Policlinico Umberto I ("La Sapienza" University of Rome, Italy). The patient population comprised 29 men and 36 women, mean age 43.7 ± 10.6, with a Glasgow Coma Scale ≤8. Conditions leading to NSICU admission are reported in Table 1. The median time interval between intubation of the trachea and the tracheostomy procedure was 6.0 days (range, 3–14 days, interquartile range 3 days). The mean operating time (interval between tracheal puncture and endoscopic confirmation of tracheostomy tube placement) was 10.4 ± 4.9 min. Tracheostomies were successfully performed in 63 of 65 patients, whereas 2 cases were shifted to a surgical procedure because of difficult intraoperative airway management. Intraoperative complications were two cases of serious bleeding, resolved with open ligature (with no need for red blood cell transfusions), and eight cases of anterior ring fractures, identified by bronchoscopy at the second/third tracheal ring level, with no migration of cartilage fragment or posterior tracheal injury. No Percutwists were inserted paratracheally, nor did a pneumothorax or pneumomediastinum occur.

Table 2. Mean Values of Monitored Parameters

	Baseline	Tube replacement	Screwing dilation	Trachea cannulation	End of procedure	*P*
MAP mm Hg	94.3 ± 14.7	95.2 ± 18.3	97.6 ± 11	95.8.1 ± 10.9	90.8 ± 9.1	0.054
ICP mm Hg	12.4 ± 3.8	12.9 ± 5.5	12.0 ± 4.9	12.7 ± 4.1	11.4 ± 3.6	0.051
CPP mm Hg	82.1 ± 16.2	83.7 ± 15.5	85.7 ± 13	80.9 ± 14.1	79.1 ± 17.6	0.134
Pao_2 mm Hg	125.3 ± 24	299.9 ± 45.1	287.5 ± 47.7	300.5 ± 40.7	169.3 ± 39.2	<0.001
$Paco_2$ mm Hg	34.2 ± 8.5	36.4 ± 9.3	35.6 ± 6.5	34.7 ± 5.7	34.4 ± 7.9	0.198

MAP = mean arterial blood pressure; ICP = intracranial pressure; CPP = cerebral perfusion pressure; Pao_2 = oxygen arterial tension; $PaCO_2$ = carbon oxide arterial tension.

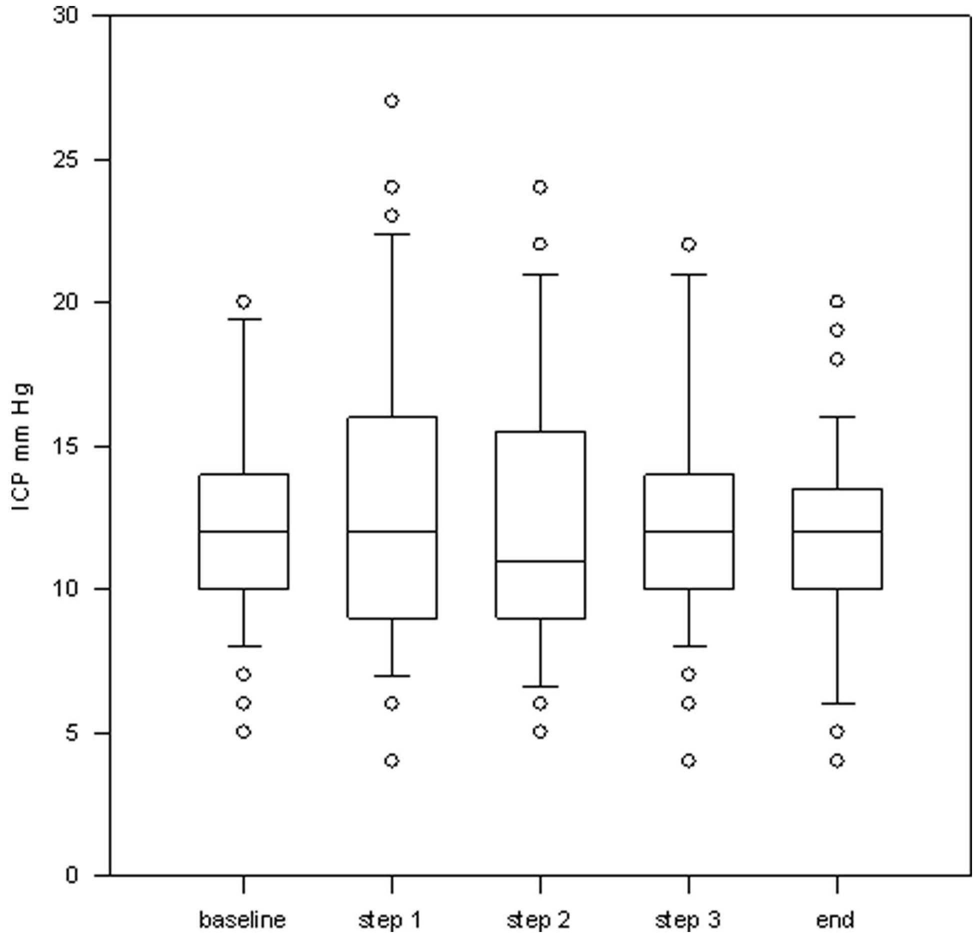

Figure 1. Box-Plot of intracranial pressure during Percutwist tracheostomy. Baseline, step 1: tube replacement, step 2: tracheal dilation, step 3: tracheal cannulation, end: end of procedure.

Eighteen episodes of intracranial hypertension lasting more than 3 min were recorded in 11 patients. Eight episodes occurred during repositioning and/or replacement of the ETT, eight episodes during dilation, and two episodes during cannula placement. ICP increased up to 27 mm Hg for 6 min in only 1 patient, which was related to a respiratory complication (cuff rupture). Another patient suffered a short-term ICP increase (up to 5 min) with a maximal value of 25 mm Hg.

No statistically significant modification of monitored variables was recorded except for Pao_2, which constantly increased throughout the procedure (Table 2). ICP and MAP values did not increase significantly during the procedure (P = 0.051 and P = 0.054, respectively) and returned to baseline at the end of the procedure (Fig. 1, Table 2). The means of ICP (difference between ICP at each time point versus baseline) during all phases of the procedure were +0.46 mm Hg at tube replacement phase, −0.33 mm Hg at the dilation phase, +0.32 at trachea cannulation and −0.96 at the end of the procedure (P = 0.104). The average CPP values were preserved in all patients during all phases of the procedure.

We observed intraoperative hypercarbia in 10 of 65 (15%) patients. Unintentionally, hypercarbia was already present at baseline in 6 patients (maximum $Paco_2$ value 44 mm Hg); 4 of 65 patients (6%) developed abnormal $Paco_2$ during the procedure ($Paco_2$ <45 mm Hg in all patients). All patients were followed up until discharge from the hospital. The average stay was 17 ± 4.7 days, and no patients died for reasons related to the tracheostomy procedure.

DISCUSSION

Elective percutaneous tracheostomy in patients on long-term ventilation has become widely recognized as the airway management of choice. A tracheostomy procedure carries the risk of intraoperative hypoventilation and/or hemodynamic instability.[15] In brain-injured patients exacerbation of intracranial hypertension, arterial hypotension and hypoxia are considered predictive factors of mortality and morbidity.[4] Accordingly, the major concern during tracheostomy procedures in these patients is to ensure airway management while providing systemic and cerebral hemodynamic stability.

The present study is the first to evaluate the effects of the Percutwist tracheostomy technique on ICP and CPP in brain-injured patients. Our results showed that ICP is affected by this procedure, but the ICP increase was transitory and mainly confined within the normal ICP range. The fluctuation of ICP during tracheostomy was close to statistical significance ($P = 0.051$), but slight ICP increases are unlikely to be clinically meaningful. Nevertheless, we observed 18 episodes of intracranial hypertension; these episodes did not translate into significant decreases in CPP and, in fact, in all cases CPP values never decreased below 60 mm Hg. Since significant predictors of mortality are duration of hypotensive and hypoxemic insults,[4] our results demonstrated that Percutwist tracheostomy was not a burden of secondary insults in head-injured patients.

Since neurological impairment is not always associated with the early stage of cerebral disease[16] and given that early tracheostomy may shorten the duration of mechanical ventilation and length of ICU stay,[17] the appropriate timing for tracheostomy must be carefully considered on the basis of ICP stability in each patient.

Repeated blood gas analysis showed intraoperative hypercarbia in 10 of 65 patients (15%). Six patients affected by pneumonia and/or thoracic trauma had abnormal $Paco_2$ values at baseline, and 4 of 65 patients (6%) developed hypercarbia during the procedure. The maximum $Paco_2$ value was 46 mm Hg, recorded in 2 patients during ETT replacement. In a few cases (3 of 10 patients), the episodes of intracranial hypertension were associated with hypercarbia. In 1 patient, ICP increased to 27 mm Hg during ETT replacement, and in the other 2, the ICP peak was limited to 24 mm Hg. The lack of clinical impact of CO_2 increase in these patients was substantiated by ICP and CPP stability.

Contrary to Dosemeci et al.[18] who reported 56.7% of patients with hypercarbia during Grigg's tracheostomy, we observed fewer respiratory complications and no statistically significant variations of $Paco_2$ during Percutwist tracheostomy. Since hypercarbia is one of the major factors responsible for ICP increase in brain-injured patients, the use of a tracheostomy technique, which allows safe ventilation, may be an advantage in these patients. These differences may be explained by the use of a single dilator, instead of multiple dilators, which minimizes the decrement in airway pressure, thus improving the efficacy of ventilation.[7,19] In addition, the Percutwist's screw helps maintain an open tracheal lumen since the device is able to create a stoma which pulls up the trachea, while reducing the airway's leakage and resistance.

Previous authors have compared the neurophysiologic consequences surgical versus percutaneous tracheostomy in brain-damaged patients.[11] Stocchetti et al.[12] reported a significant increase in ICP at the time of cannula placement during three different tracheostomy techniques. Only one technique, the trans-laryngeal method (Fantoni), was described as a safe procedure in severely brain-damaged patients. As opposed to the Fantoni method, in which the ETT is substituted with a smaller one, the Percutwist technique allows for the use of the same ETT size (or even larger), thus optimizing mechanical ventilation.

Profound analgesia and myorelaxation are necessary to blunt intracranial responses to any surgical procedure. In our study, the depth of anesthesia was assessed clinically, keeping CPP values above 60 mm Hg in all patients. Significant increases in heart rate, MAP and/or autonomic signs of inadequate anesthesia were monitored and depth of anesthesia titrated accordingly. We believe that, in our series, adequate anesthetic management was one of the major determinants able to blunt intracranial sympathetic responses to tracheostomy procedures. In addition, ICP and CPP stability found in our patients was also related to the appropriate position of the head during tracheostomy, leading to a normal cerebral venous outflow. Moreover, the vertical traction of the anterior tracheal wall during the dilation maneuver, did not increase airway resistance, thus preventing significant ICP increases due to hypercarbia.

We acknowledge that this is a modestly sized study without a control group of different PDTs for comparison; moreover, the safety of the technique was tested in a selected sample of patients with stable ICP and cerebral compliance was not measured in our study. More prospective studies comparing the Percutwist tracheostomy with other PDT methods are necessary to better define neurophysiological consequences of different techniques on ICP and CPP.

In conclusion, the Percutwist tracheostomy technique used in brain-injured patients with stable ICP <20 mm Hg did not clinically significantly increase ICP or $Paco_2$ and was not associated with neurological deterioration. This was the case whether tracheostomy was performed early or late.

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