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CLINICAL ARTICLE

Analysis of intracranial pressure changes during early versus late percutaneous tracheostomy in a neuro-intensive care unit

Hasan Kocaeli · Ender Korfalı · Özgür Taşkapılıoğlu · Tekin Özcan

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Abstract
Background We aimed to investigate intracranial pressure (ICP) changes during early versus late bedside percutaneous tracheostomy (PT) in a neuro-intensive care unit (NICU).
Methods This study included 30 patients admitted to our NICU for head trauma, subarachnoid haemorrhage, intracerebral haematoma or brain tumour with a Glasgow Coma Score (GCS) less than 8. These patients also underwent ICP monitoring. Bedside PT was performed either early (within 7 days of ventilation) or late (after 7 days of ventilation) via the Griggs system. In all patients; ICP, systemic blood pressure, heart rate, oxygen saturation (Sat O_2) and arterial blood gases were recorded 5 min before the procedure, during skin incision, during tracheal cannulation, as well as 5 min and 10 min after the procedure.
Findings Thirty patients, 18 male and 12 female, with various intracranial pathologies between ages 18 and 78 (mean 38.7±20) were identified. The admission GCS ranged between 4 and 11 (median 7). Physiological variables did not differ significantly between the two groups. In the early group, ICP values measured 5 min before the procedure, during skin incision, during tracheal cannulation, as well as 5 min and 10 min after the procedure were 15.1±5.2, 22±10.1, 28.4±13.7, 17.3±7.1, 13.8±5.0 mmHg, respectively. In the late group, these values were 14.2±4.5, 17.2±5.5, 21.5±8.0, 15.1±5.3 and 12.4±4.1 mmHg. There was no significant difference between the early or late groups in terms of ICP increases during these predetermined 5 time points.
Conclusions In patients with decreased intracranial compliance, a relatively minimally invasive procedure such as PT may lead to significant increases in ICP. The timing of PT does not seem to influence ICP, mortality, pneumonia or early complications. During the PT procedure, ICP should be closely monitored and preventive strategies should be instituted in an attempt to prevent secondary insult to an already severely injured brain.

Keywords Intracranial pressure monitoring · Percutaneous tracheostomy · Griggs system · Neurointensive care unit

H. Kocaeli (✉) · E. Korfalı · Ö. Taşkapılıoğlu · T. Özcan
Department of Neurosurgery,
Uludağ University School of Medicine,
Bursa, Turkey
e-mail: hasankocaeli@yahoo.com

Introduction

Percutaneous tracheostomy (PT) is a common surgical procedure that is used for patients undergoing long-term mechanical ventilation. From a practical standpoint, the main advantage seems to be the opportunity to perform PT at the bedside, obviating transport to the operating room and any transport-related complications [1, 2]. Recently, much debate has focused on the timing of tracheostomy and whether it should be performed earlier [18]. Although some studies reported objective criteria, in our daily routine, the decision to perform a PT is often made on the basis of expert opinion rather than easily measured patient characteristics [9, 11]. Despite the lack of consensus for the timing of PT, studies have shown that early PT shortens intensive care unit (ICU) stay and lowers the incidence of pneumonia [10, 12]. The procedure has its own inherent complications and carries the risk of secondary insult to an already injured brain due to various factors such as hypoventilation, hypercarbia, hypoxaemia, arterial hypertension, improper head position, and suboptimal level of analgesia [5, 19, 20]. These factors may have an impact on the intracranial volume and exacerbate intracranial hypertension (IC-HTN), which is the leading cause of mortality and morbidity in several neurological pathologies. Although the procedure is common in neurosurgical patients, the number of patients that have undergone continuous intra-operative intracranial pressure (ICP) monitoring is relatively small. Furthermore, the observed changes in ICP during the PT procedure varies in terms of the presence and magnitude of pressure increases [2, 4, 8, 20]. The purpose of this study was to investigate the effects of PT, performed either early (within 7 days of ventilation) or late (after 7 days of ventilation), on ICP in a group of neurosurgical patients with brain damage due to various intracranial conditions.

Methods and materials

Between October 2004 and October 2006, 30 consecutive comatose patients (Glasgow Coma Score <8), who were treated in the neurosurgical ICU of the Uludağ University, Department of Neurosurgery due to various intracranial pathologies and underwent PT via the Griggs system, were included in this study. Clinical characteristics of our patients are presented in Table 1. Indications for PT were the likelihood of significant disability and need for mechanical ventilation greater than 2 weeks [15]. Exclusion criteria were abnormal anatomy, age less than 16 years, unstable ICP (defined as ICP>20 mmHg), bleeding diathesis, local infection and previous tracheostomy. Written informed consent was obtained from the patients' next of kin. In all patients, we obtained intra-operative ICP values using an intra-parenchymal monitoring device (Olm Intracranial Pressure Monitoring Kit, Model 110-4B, Integra Neurosciences, Camino, NJ, USA). During the PT procedure, five main timepoints were determined: (1) the baseline was 5 min after positioning the patient, induction of anaesthesia when a stable depth of anaesthesia was established; (2) skin incision; (3) insertion of tracheal cannula; (4) 5 min after placement of cannula; and (5) 10 min after placement of cannula. In all of these time points, ICP, systemic blood pressure, heart rate, oxygen saturation (Sat O_2) and arterial blood gases were recorded. In an attempt to investigate the effect of PT timing on ICP, patients were divided into two groups as early and late. For the purpose of this study, early tracheostomy was defined as 7 days or less and late tracheostomy was greater than 7 days.

Table 1 Clinical characteristics of patients who underwent PT

	Early	Late
Number of patients	15	15
Mean age (year)	38.20	43.93
Cause of admission to ICU		
Trauma	11	7
ICH	1	4
SAH	2	2
Tumour	1	2
Median GCS	8	9
Median time to PT (days)	5	9
Median duration of PT (days)	12	8
VAP	3	2
Mortality (%)	4 (26.6)	6(40)
Complications		
Aborted procedure	0	1
Bleeding	2	1
Emphysema	2	1
Ventilation problem	1	1

Surgical technique

Premedication was performed with 0.01 mg/kg Atropine sulfate. A Propofol infusion was started at a rate of 1–3 mg/kg/h and supplemented with intravenous boluses of 0.1 mg/kg Fentanyl and 0.5 mg/kg Atracurium to maintain muscle paralysis and analgesia. Additional subcutaneous local anaesthesia was applied in the region of the planned incision down to the trachea with 3 to 5 ml of a 1% lidocaine solution. Patients were mechanically ventilated and the baseline level of $PaCO_2$ was maintained. FiO_2 was raised to 1.0 immediately before insertion of the cannula and lowered to the initial value at the end of the procedure. In this study, we employed the Griggs technique for PT, which is described in detail previously [6]. In brief, a small horizontal skin incision is made over the second tracheal ring and the subcutaneous tissue is dissected bluntly. After tracheal puncture, a guide wire is inserted and a specially designed dilation forceps (Portex kit, UK) is introduced into the trachea and spread once. Finally, the tracheal cannula was inserted and connected to the ventilator. Approximating skin stitches were performed, as needed. Data were analysed using SPSS for Windows version 13.0 (SPSS Inc). All values are depicted as means±standard error of the mean. The compatibility of continuous variables to normal distribution was examined with the Shapiro Wilk test. Continuously measured variables included ICP, heart rate, blood pressure, pulse, pH, PO_2, PCO_2 and were evaluated within the groups by using Wilcoxon signed rank test and paired-*t* test. Differences between the early and late groups were evaluated using the Mann–Whitney *U*-test. A probability value of $p<0.05$ was considered significant.

Results

Thirty patients (18 male and 12 female, aged 17 to 77 (mean 38.7±20)) with various intracranial pathologies such as head trauma, subarachnoid haemorrhage, intracerebral haematoma or brain tumour were identified. The mean duration of pre-operative oro-tracheal intubation in the early and late groups was 4.53±0.6 days and 9.06±1.2 days, respectively. Admission GCS ranged from 4 to 11 (median 7). In the early group, ICP values measured 5 min before the procedure, during skin incision, during tracheal cannulation as well as 5 min and 10 min after the procedure were 15.1±5.2, 22±10.1, 28.4±13.7, 17.3±7.1 and 13.8±5.0 mmHg, respectively. In the late group, the values were 14.2±4.5, 17.2±5.5, 21.5±8.0, 15.1±5.3 and 12.4±4.1 mmHg, respectively (Fig. 1). There was no significant difference between the early or late groups in terms of ICP increases during these predetermined five time points (Fig. 1, Table 2). All patients were monitored for ventilator associated pneumonia (VAP), early complications and mortality. All tracheostomies were performed with no significant bleeding or oxygen desaturation, albeit in five patients, minor bleeding from the surgical site was stopped with gentle compression with gauze. The mean duration of cannulation was 17±16.2 days and there were 10 (33.3%) deaths (four in the early group and six in the late group). The incidence of VAP was five (two in the early and three in the late group).

Discussion

PT is a common procedure used for airway management in patients who cannot be easily liberated from mechanical ventilation. Despite the ongoing controversy on timing of tracheostomy, performing the procedure at an earlier stage than is currently practised has been suggested to shorten the duration of artificial ventilation and length of stay in

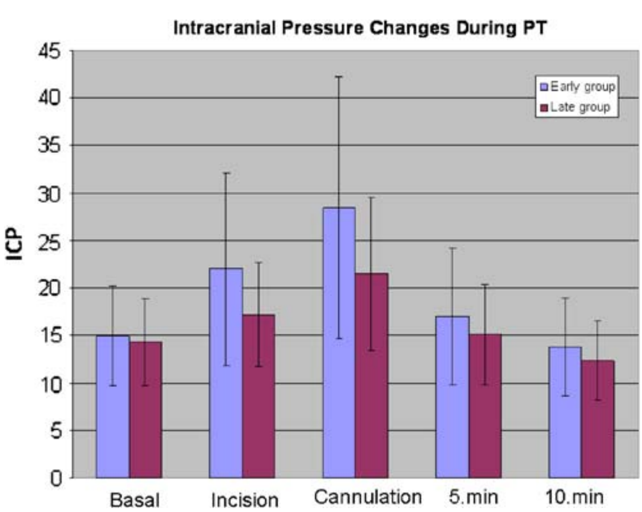

Fig. 1 Graphic demonstration of the ICP changes during a PT procedure. ICP values did not differ between the groups although statistically insignificant rises were observed during the cannulation phase of the procedure

the ICU [5]. These advantages include, improved patient comfort by reducing oral and laryngeal irritation, facilitation of weaning by reducing respiratory resistance, improving pulmonary toilet, as well as patient autonomy and communication. Also decrease of sedation requirements as well as reduced frequency of VAP, length of ICU stay and cost have been reported [7, 12, 14, 16]. However, the procedure is not without risk and may be associated with complications such as hypoventilation, hypercarbia, hypoxaemia, arterial hypertension, stomal haemorrhage and infection, pneumomediastinum, pneumothorax, bleeding, tracheal stenosis and rarely tracheoinnominate fistula [5, 20]. Recently, much debate has focused on the timing of tracheostomy and whether it should be performed earlier. Although early tracheostomy has been suggested to offer some advantages, such as shortening the duration of ICU stay and reducing complications, the fact that the highest rates of IC-HTN occurs within the first days after hospitalisation requires careful consideration [5]. On the other hand, the time course of IC-HTN can be variable and late ICP increases have also been reported [21]. Despite recent reports that have attempted to address this question, the indications and patient selection remains to be elucidated [18]. PT has also found wide application in the NICU and currently the procedure is being performed by neurosurgeons in our facility due to the fact that the neurosurgical patient population differs from the common patient in that they are more vulnerable to secondary insults that may not be appreciated by other specialists [2, 11].

During the acute stages after traumatic brain injury, autoregulation may be significantly deranged and cerebral blood flow is low. Consequently, patients may be even more susceptible to any secondary insult, which would contribute to a poorer outcome [13]. Furthermore, the transport of such patients to the operating room has been shown to cause secondary increases in ICP [1]. Technically, the use of intra-operative endoscopic guidance has been found to be helpful in the safe placement of the puncture cannula and wire and in ensuring non-penetration of the posterior wall of the trachea [2, 20]. However, the technique is not without complications and carries a risk of occult hypercarbia due to airway obstruction, adds complexity to the procedure and risks potential endoscope damage [4]. Although the procedure is common in the neurosurgical patient, the number of patients receiving continuous intra-operative ICP monitoring is relatively small and the reported ICP values during the PT procedure are variable [2, 4, 8, 19, 20]. In the 38 patients who underwent PT via the Ciaglia method, Gumprecht et al. reported no increase in ICP above 20 cm H_20 [3, 8]. In 13 of 35 neurosurgical patients, Escarment et al. noted insignificant ICP elevations during the tracheal cannulation phase, with a mean value of 24 mmHg, but did not detect

Table 2 Numerical values of physiological parameters observed during the PT procedure

	Early group	Late group
Heart rate (per minute)		
Basal	93.9±20.4	86.1±14.9
Incision	102.4±23.1	96.6±15.7
Cannulation	114.0±15.0	102.6±16.8
5 min after	104.8±17.1	94.1±10.5
10 min after	98.4±18.1	89.6±14.1
Blood gases		
pH $_{Basal}$	7.38±0.06	7.39±0.06
pH $_{Incision}$	7.39±0.05	7.39±0.06
pH $_{Cannulation}$	7.38±0.06	7.38±0.06
pH $_{5\ min}$ after	7.36±0.07	7.39±0.06
pH $_{10\ min}$ after	7.38±0.06	7.38±0.05
pO_2 $_{Basal}$	172.8±84.8	156.2±38.6
pO_2 $_{Incision}$	182.0±73.5	156.3±47.5
pO_2 $_{Cannulation}$	178.3±94.9	134.6±43.9
pO_2 $_{5\ min}$ after	193.9±94.6	154.4±42.7
pO_2 $_{10\ min}$ after	191.1±106.6	171.5±46.5
pCO_2 $_{Basal}$	37.6±6.2	36.6±6.9
pCO_2 $_{Incision}$	36.6±6.0	36.5±5.8
pCO_2 $_{Cannulation}$	38.0±75.6	41.0±6.0
pCO_2 $_{5.min}$ after	37.4±51.1	37.6±7.2
pCO_2 $_{10.min}$ after	33.6±82.2	37.1±5.0
Blood pressure (mmHg)	Systolic/Diastolic	Systolic/Diastolic
Basal	128.8±29.8/69.0±11.4	139.8±23.4/77.6±15.6
Incision	134.3±31.5/73.2±14.5	139.1±29.5/76.4±17.4
Cannulation	146.1±26.7/76.6±13.9	156.1±29.4/83.6±15.2
5 min	134.6±27.4/76.0±12.7	141.4±23.1/75.9±13.4
10 min	130.9±22.8/70.1±12.0	139.6±18.6/74.3±12.9
Pulse rate		
Basal	98.8±0.9	97.8±3.2
Incision	98.4±2.6	97.3±4.8
Cannulation	98.6±1.3	97.0±3.0
5 min after	97.8±4.8	98.0±4.2
10 min after	97.6±5.8	97.0±9.4
ICP (mmHg)		
Basal	15.1±5.2	14.2±4.5
Incision	22.0±10.1	17.2±5.5
Cannulation	28.4±13.7	21.5±8.0
5 min after	17.3±7.1	15.1±5.3
10 min after	13.8±5.0	12.4±4.1

any changes in CPP [4]. Börm and Markus reported their PT experience in 54 neurosurgical patients, 14 of whom also underwent ICP monitoring during the procedure with two different methods. They found no increase in ICP above 20 mmHg and the mean ICP value was 13 mmHg in the Griggs group [2]. Stocchetti et al. reported 20 patients admitted to the ICU with head injury, SAH or brain tumour with a GCS <8 who underwent PT under detailed neuromonitoring. They detected IC-HTN in five of their patients during the tracheal cannulation, which rose over 20 mmHg [20]. In our study, the most significant rise in ICP was also detected during the tracheal cannulation phase, with a mean value of 28.4±13.7 and 21.5±8.0 in the early and late groups, respectively. Our findings are similar to those reported by Stocchetti et al. who observed ICP increases with three different tracheostomy methods (percutaneous dilatational, standard surgical and translaryngeal), which was more evident at the time of tracheal cannula placement [19, 20].

Several factors that can cause a rise in the ICP during the PT procedure should be considered. Physiological parameters should be closely monitored and should not differ significantly among groups.

Optimal levels of analgesia and myorelaxation are necessary to blunt the intracranial response to any surgical procedure, which is also true for PT. The levels of analgesia may be suboptimal in this study because of the higher mean ICP values during cannulation (which is not statistically significant). Since cannula insertion into the trachea is a well-known source of intense pain and may not be alleviated with standard doses of analgesic medications, which do not cause changes in physiological parameters. On the other hand, deepening the anaesthesia may cause arterial hypotension and the possible protective effect of deep anaesthesia may be counterbalanced by a reduction of CPP [19].

The PT procedure has been reported to be associated with hypercarbia and acidosis, which has been reported to be frequent and may go unnoticed since conventional CO_2 monitoring such as blood gas analysis, which is the method used in our study, may fail to detect perturbations in CO_2 [17].

ICP is affected by the resistance to venous outflow from the intracranial space. Another potential insult is the position of the patients' head and the effect of neck manipulation on cerebral venous outflow during the procedure. The standard position for patients with severe head injuries in most NICUs is the semi-recumbent 30° head elevation which, at least within the first 24 h after injury, leads to a consistent reduction in ICP and improvement in CPP without concomitant deleterious changes in cerebral oxygenation [13]. In contrast to the hyperextension position that is used during open tracheostomy, patients' heads are kept at a 30° neutral position in the PT technique and close monitoring of ICP allows the operator to adjust the head reposition. Although we tried to limit the magnitude and length of tracheal manipulations, the compression of neck structures produced by the insertion of dilators have been reported to elevate internal jugular pressures during percutaneous dilatational tracheostomy measured at the superior jugular bulb [19].

Our report adds additional data to the scant literature of ICP changes occurring during PT in a group of comatose neurosurgical patients that underwent PT as an early or late procedure. To the best of our knowledge, this study is the first report that specifically addresses ICP changes that occur during early and late PT, which suggests that the timing of PT does not influence ICP, although there is a risk for significant ICP increase during tracheal cannulation.

Our study has some limitations. The pO_2 value at the time of cannulation is lower than expected. Although the inspired FiO_2 was raised to 1.0 before cannulation we suspect that the time that elapses during removal of the endotracheal tube, insertion of the tracheal cannula and attachment of ventilator tubings to the cannula as well as a leak of air from the tracheal opening during the dilatation manoeuvre(s) might have caused a fall in the level of pO_2.

In this study, the timing of PT did not reveal any significant differences in terms of early complications, ICP rises during the procedure, VAP or mortality. Physicians that take care of patients with decreased intracranial compliance should be aware of the possibility of ICP rises during a relatively minimally invasive procedure such as a bedside PT. General preventive strategies should be implemented in an attempt to avoid secondary insult to an already injured brain.

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Comment

This study addresses the question of whether early or late percutaneous tracheostomy produce different changes in intracranial pressure as a marker of potential and this may be important in patients with reduced compliance or disturbed autoregulation.

As expected the procedure produced a rise in ICP which subsided within 10 min with no significant difference in the change in ICP between the early and late groups.

Because of the small sample size it is not possible to determine whether initial GCS or age is a confounding factor but the data suggest that in this patient group there is so significant difference in the change in ICP between the early and late groups.

But, as the authors point out, close monitoring of the ICP and appropriate interventions should be undertaken to minimise the effects of secondary insults to an already injured brain.

Iain Chambers