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SCIENTIFIC ARTICLE

Subjective method for tracheal tube cuff inflation: performance of anesthesiology residents and staff anesthesiologists. Prospective observational study☆

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Abstract

Background and objectives: Poor monitoring of tracheal tube cuff pressure may result in patient complications. The objective method of using a manometer is recommended to keep safe cuff pressure values (20–30 cm H_2O). However, as manometers are not readily available, anesthesiologists use subjective methods. We aimed to assess appropriateness of a subjective method for attaining cuff pressure and the expertise level of manometer handling among anesthesiology staff and residents in a university teaching hospital.

Methods: Prospective observational study, recruiting participants that performed tracheal intubation and the subjective method for tube cuff inflation. Patients with difficult airway, larynx and trachea anatomic abnormality and emergency procedures were not included. Up to 60 minutes after tracheal intubation, an investigator registered the cuff pressure using an aneroid manometer (AMBU®) connected to the tube pilot balloon.

Results: Forty-seven anesthesiologists were included in the study – 24 residents and 23 staff. Mean (SD) and medians (IQR) measured in cmH_2O were, respectively, 52.5 (27.1) and 50 (30–70). We registered 83% of measurements outside the recommended pressure range, with no difference between specialists and residents. The level of expertise with the objective method was also similar in both groups. Pressure adjustments were performed in 76.6% of cases.

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Conclusion: The subjective method for inflating the tracheal tube cuff resulted in a high rate of inadequate cuff pressures, with no difference in performance between anesthesiology specialists and residents.

PALAVRAS-CHAVE
Intubação traqueal;
Tubo traqueal;
Pressão do balonete;
Manômetro;
Anestesiologista

Insuflação de balonete de tubo traqueal por método subjetivo: desempenho de médicos residentes e especialistas em anestesiologia. Estudo prospectivo observacional

Resumo
Justificativa e objetivos: O controle inadequado da pressão dos balonetes dos tubos traqueais pode resultar em complicações. A técnica objetiva com uso de manômetro é a recomendada para manutenção de valores seguros de pressão (20–30 cm H_2O). Mas como este instrumento é pouco disponível, os anestesiologistas recorrem a técnicas subjetivas. O objetivo deste estudo foi avaliar a adequação da técnica subjetiva para obtenção das pressões dos balonetes e o nível de experiência com uso do manômetro entre médicos especialistas e residentes de anestesiologia de um Hospital Universitário.
Método: Estudo observacional prospectivo, com participantes que realizaram intubação traqueal e técnica subjetiva para insuflação dos balonetes. Pacientes com via aérea difícil, anormalidades anatômicas de laringe e traqueia, risco de broncoaspiração e os casos de emergência não foram incluídos. Até 60 minutos após a intubação, um investigador registrava a pressão do balonete utilizando um manômetro aneroide (AMBU®) conectado ao balonete guia do tubo.
Resultados: Quarenta e sete anestesiologistas foram incluídos no estudo – 24 residentes e 23 especialistas. As pressões (cm H_2O) média (DP) e mediana (IQR) encontradas foram respectivamente; 52,5 (27,1) e 50 (30–70). Da amostra, 83% estavam fora da faixa adequada de pressão, sem diferença entre especialistas e residentes. O nível de experiência com a técnica objetiva também foi semelhante entre os grupos. Correção da pressão foi realizada em 76,6% dos casos.
Conclusões: A técnica subjetiva para insuflar os balonetes dos tubos traqueais resultou em alta prevalência de pressões inadequadas, sem diferença no desempenho entre especialistas e residentes.

Background

Tracheal Intubation (TI) is one of the fundamental skills required for anesthesia practice, emergency and critical care, and in pre-hospital care scenarios. Airway management-related complications are among the most frequent causes of litigation in medical practice.[1,2]

To improve airway protection, the tube used for TI has a cuff around its distal portion that must be inflated via pilot balloon valve to seal the space between the tube and trachea walls, at a recommended pressure between 20 and 30 cm H_2O.[3]

Non-compliance to the recommended pressure may lead to complications. Cuff inflation pressures below 20 cm H_2O increase the risk of gas leakage compromising lung ventilation, in addition to facilitating aspiration of secretions and oropharyngeal and gastric contents.[4] Inflation pressures kept above 30 cm H_2O may overcome the local capillary pressure, reducing blood flow to the mucosa of the anterolateral wall of the trachea. Pressures above 50 cm H_2O can cause complete vascular occlusion and tracheal ischemia.[5]

As a consequence, to prevent complications, the tracheal tube cuff pressure must be kept at the minimum value possible to ensure adequate tracheal mucosa blood flow, but must be high enough to secure safe sealing of the space between the tube and trachea walls.[6–10]

Distinct strategies, using subjective and objective methods, have been proposed to attain adequate control of the cuff pressure and reduce the risks of complications.[11–17] However, evidence adds up against using subjective methods, and also signals toward a non-correlation between measured cuff pressure and age, sex, height and weight of patients. Additionally, pressures measured do not differ as a function of tracheal tube size or of the expertise of the professional executing the procedure.[18–21]

Thus, the main objective of the present study was to measure tracheal tube cuff pressure inflated by the subjective method in patients submitted to TI by staff physicians specialized in anesthesiology or anesthesiology residents of a teaching university hospital. We also studied the level of knowledge concerning the minimum and maximum ideal limits of the tracheal tube cuff pressure and the expertise of the participant physicians regarding the use of analogic

manometers to perform the objective method for setting such pressures. The assumption was that tracheal tube cuff inflation using the subjective method would result in a high prevalence of cuff pressures above or below the recommended limits, and that the knowledge of recommended cuff pressure levels and the level of expertise with manometers would be low, with no significant difference between staff and residents.

Methods

This observational prospective study was performed between June and November, 2016 at a university teaching hospital, after approval by the Ethics in Research Committee of the organization (CAAE: 44486515.7.0000.5208). All ethical aspects related to research with human subjects were obeyed.

After obtaining patients' informed consent, 48 subjects with ages ranging from 18 and 65 years underwent general anesthesia with placement of a tracheal tube and the subjective method with inflation and digital palpation of the pilot balloon to establish the cuff pressure. The laryngoscopy, tracheal intubation and cuff inflation were performed by staff physicians with specialization in anesthesiology, or by resident year 1 (R1), resident year 2 (R2) or resident year 3 (R3) anesthesiology medical residents. Patients presenting anticipated difficult airway, risk of bronchoaspiration, previously known tracheal or larynx anatomic abnormality or emergency procedures were excluded. We used the orotracheal technique in all patients, with 8 or 8.5 mm internal diameter tubes for males and 7 or 7.5 mm for females.

Up to 60 minutes after tracheal intubation, the cuff pressure was measured by the investigators using the objective method with an analogic manometer (AMBU®) connected to the pilot balloon. Data was registered on a dedicated form.

Whenever the pressure was outside the recommended limits, the physician in charge of the case was communicated by the investigator, so the physician could make a decision on correcting the finding.

The sample size was estimated taking into account the total number of residents (R1+R2+R3) in training at operating rooms during the period of the study, added to a similar number of hospital staff anesthesiology specialists, to enable paired observations, resulting in a total of 48 participants (24 staff anesthesiologists and 24 anesthesiology residents). Each participant (staff or resident) and her or his respective patient had their data collected and registered only once during the study.

For data presentation, qualitative variables were described by absolute and percentage values, while quantitative variables were shown as means, Standard Deviation (SD), medians, minimum and maximum Interquartile Range (IQR). In order to study associations and comparisons between groups, Pearson Qui-Square test and Fisher's exact test were used for qualitative variables.

Results were considered statistically significant when their descriptive levels (p-values) were below 0.05. Statistical analysis was performed with SPSS for Windows version 21.0 software.

Table 1 Profile of the professionals studied and the cuff pressure for all groups.

Variables	n = 47
Professional	
Resident (R1)	8 (17.0%)
Resident (R2)	9 (19.1%)
Resident (R3)	7 (14.9%)
Staff	23 (48.9%)
Cuff pressure (cm H_2O)	
Minimum – Maximum	12–120
Mean (SD)	52.5 (27.1)
Median (IQR)	50 (30–70)
Cuff pressure (cm H_2O)	
Below recommended	5 (10.6%)
Recommended	8 (17.0%)
Above recommended	34 (72.3%)
Professional knows recommended pressure	28 (59.6%)
Occasional use of manometer	30 (63.8%)
Routine use of manometer	2 (4.3%)
Corrected cuff pressure value outside recommended range	36 (76.6%)
Drop of cuff pressure during measurement	0 (0%)
Tracheal extubation during measurement	0 (0%)
Cuff damage during measurement	0 (0%)

SD, Standard Deviation; IQR, Interquartile Range.

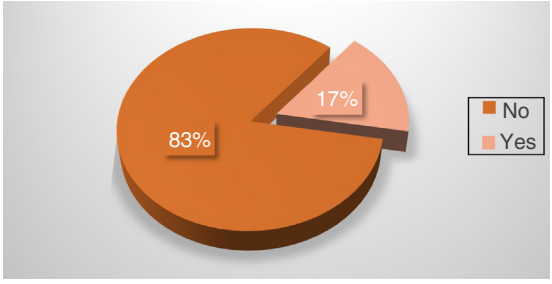

Fig. 1 Percentage of participants, according to recommended (20–30 cm H2O) cuff pressure measured (n = 47).

Results

Of the 48 study participants, one staff member case was lost, after realizing data had been collected from the same participant previously (duplication). Thus, we analyzed data collected from 47 participants (24 residents and 23 specialists), whose patients were submitted to general anesthesia, tracheal intubation, and on whom the subjective method was used to inflate the tracheal tube cuff.

Table 1 describes the profile of participating professionals, values of cuff pressure measured and corrected, the extent of knowledge of the recommended limits for cuff pressure, participants' manometer use expertise and the adverse events during the study.

Fig. 1 describes the percentage of participants, according to the presence of recommended cuff pressure measurements.

When staff and residents were compared regarding measured cuff pressures, we found no statistically significant difference between the groups (Table 2).

Table 2 Comparison between specialists and residents regarding measured and corrected cuff pressures (n = 47).

Variables	Specialists (n = 23)	Residents (R1+R2+R3) (n = 24)	*p*
Cuff pressure			
Below	3 (13.0%)	2 (8.3%)	0.801 F
Recommended	3 (13.0%)	5 (20.8%)	
Above	17 (73.9%)	17 (70.8%)	
Recommended pressure			
No	20 (87.0%)	19 (79.2%)	0.701 F
Yes	3 (13.0%)	5 (20.8%)	
Corrected Pressure	18 (78.3%)	18 (75.0%)	0.792 χ^2

F, Fisher's exact test; χ2, Chi-Square test.

Table 3 Comparison between staff and residents as to knowledge of recommended range for tracheal cuff pressure and use of objective method employing manometers (n = 47).

Variables	Staff (n = 23)	Residents (R1+R2+R3) (n = 24)	*p*
Knows recommended pressure	16 (69.6%)	12 (50.0%)	0.172 χ^2
Occasional use of manometer	16 (69.6%)	14 (58.3%)	0.423 χ^2
Routine use of manometer	2 (8.7%)	0 (0%)	0.234 F

F, Fisher's exact test; χ2, Qui-Square test.

When comparing answers of staff and residents to questionnaires, in regard to knowledge of the recommended range for tracheal cuff pressure and the occasional or routine use of a manometer to perform the objective method for cuff inflation, we did not find a statistically significant difference between the groups (Table 3).

When comparing residents according to their PGY (R1, R2 and R3), we did not find a statistically significant difference for pressures measured in cuffs inflated by the subjective method (Table 4).

Concerning the knowledge of the recommended maximum and minimum values for cuff pressure there was no difference between R1, R2 and R3. All first, second and third-year residents confirmed having already used manometers, with no differences among them, albeit all residents having stated that manometers are not routinely available for providing general anesthesia care (Table 5).

Discussion

Tracheal intubated patients must always have tracheal tube cuff pressure kept between 20 and 30 cm H_2O. In the gold standard method to attain the recommended pressure range, the tube cuff must be inflated via pilot balloon with the help of an analogic or digital calibrated manometer that enables continuous or intermittent measurement of cuff pressure, in real time, allowing its adjustment without interruption of measurement.[17] However, these devices are considered expensive, both for acquisition and maintenance. As a consequence, although unreliable, the subjective method for cuff inflation continues to be the most used one.[16,18]

In the most frequently performed subjective technique a random amount of air is injected, via the unidirectional valve of the pilot balloon using a syringe, and the operator infers if the tube cuff pressure is adequate by digitally palpating the balloon. Studies have revealed that this method produces a mean cuff pressure ranging between 35 and 62 cm H_2O. The method results in hyperinflation explained by the great variability in the air volume required to achieve adequate cuff pressure due to variations in patient profiles, tube diameters, gases used during mechanical ventilation, and by the health professional's goal to minimize risks of pulmonary aspiration of the gastric content.[3,11,14,22,23]

In our study we tested the assumption that there was no compliance to tube cuff pressure range recommendations when a manometer was not used for tube cuff inflation, regardless of the experience of the health professional involved in the procedure. More than 80% of our patients presented an inadequately inflated tracheal tube cuff, showing pressures below, and mainly, above the recommended values by the scientific literature, with no difference between anesthesiology staff and residents.

Many studies with several designs and methods have shown the inappropriateness of subjective methods for cuff tube inflation. Patients intubated either in emergencies,[23] operation rooms,[3,5,13] or in pre-hospital settings,[19,23] without using a manometer for obtaining and maintaining adequate tracheal tube cuff pressure have shown values consistently out, largely above, the recommended range 20 to 30 cm H_2O, similar to the results observed in our study.

A prospective study that analyzed subjective tracheal tube cuff inflation using either 10 mL or 20 mL syringes showed that weight, age and height of patients had no effect on tube cuff pressure values. However, larger syringes (20 mL) resulted in statistically significant cuff pressures that were higher and outside the recommended range. Similar to our findings, the authors concluded that the subjective method is unreliable.[13]

Analyzing data related to the prevalence of cuff pressure corrections after using a manometer (76.6%), we can observe that results were similar to previously published lit-

Table 4 Comparison between residents as to values of measured and corrected cuff pressures (n = 24).

Variables	R1 (n = 8)	R2 (n = 9)	R3 (n = 7)	*p*
Cuff pressure				
Below	0 (0%)	1 (11.1%)	1 (14.3%)	0.804 F
Recommended	2 (25.0%)	1 (11.1%)	2 (28.6%)	
Above	6 (75.0%)	7 (77.8%)	4 (57.1%)	
Recommended pressure				
No	6 (75.0%)	8 (88.9%)	5 (71.4%)	0.698 F
Yes	2 (25.0%)	1 (11.1%)	2 (28.6%)	
Corrected pressure	6 (75.0%)	8 (88.9%)	4 (57.1%)	0.360 F

F, Fisher's exact test.

Table 5 Comparison amongst residents concerning knowledge of the recommended limits for tracheal tube cuff pressure and objective method for cuff inflation using manometer (n = 24).

Variables	R1 (n = 8)	R2 (n = 9)	R3 (n = 7)	*p*
Knows recommended pressure	3 (37.5%)	4 (44.4%)	5 (71.4%)	0.461 F
Occasional use of manometer	6 (75.0%)	4 (44.4%)	4 (57.1%)	0.515 F
Routine use of manometer	0 (0%)	0 (0%)	0 (0%)	–

F, Fisher's exact test.

erature, such as Galinski et al., with authors reporting 72% of corrections performed.[7]

Studies have also highlighted the absence of difference in the expertise for adequate management of cuff pressure with the subjective method, when technicians, paramedics, and physicians (anesthesiologists, emergency physicians, intensivists and residents) were compared, regardless of time of professional experience.[18,19,21,24] Hoffman et al. used an experimental model to assess the skills of faculty physician members of an emergency care medicine department to correctly inflate the tracheal tube cuff and estimate the pressure of cuff previously inflated. Similar to our results, physicians were unable to inflate the tracheal tube cuff at safe pressures using the subjective technique. The physicians were also unable to estimate the tracheal cuff pressure by digital palpation.[18]

The comparable low efficiency of staff and residents to correctly establish the cuff pressure without using a manometer found in our study endorses the results of previously published studies,[3,20] and confirms the working assumption we formulated at the studyś planning phase. It also highlights the concept that the objective method to inflate the tracheal tube cuff associated with regular measurements and corrections are simple actions requiring minimal time and should be considered as an investment in quality and safety by healthcare services.[8,13]

It should also be emphasized that staff and residents registered a comparable extent of knowledge on the recommended range of values for tracheal tube cuff pressure and a similar level of unfamiliarity for using manometers. Both findings underscore the need for continuous education, training and acquisition of devices and commitment of all participants of the health care system, mainly teaching institutions, for strategies to reduce morbidity and mortality, and to continuously improve care, teaching, research, and continued education.

One limitation of the study was the sample size, as the study was carried out in a single teaching hospital, with a small number of residents for comparison to staff anesthesiologists. Maybe a multicenter trial, with several teaching hospitals could offer more robust results, although previous published studies have confirmed our results.

Conclusions

We concluded that tracheal tube cuff inflation using the subjective method does not ensure reaching values of cuff pressure within the recommended range. Staff specialist anesthesiologists and anesthesiology residents do not present the skills to attain correct tracheal tube cuff pressures using the subjective method. They also lack knowledge of the minimum and maximum recommended cuff pressures, and the expertise on using manometers for the objective method. Therefore, we suggest the routine use of the objective technique with a manometer for tracheal tube cuff inflation and cuff pressure monitoring.

Conflicts of interest

The authors declare no conflicts of interest.

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