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Comparison and effects of two different airway occlusion times during measurement of maximal inspiratory pressure in adult intensive care unit neurological patients

Comparação e efeitos de dois diferentes tempos de oclusão da via aérea durante a mensuração da pressão inspiratória máxima em pacientes neurológicos na unidade de terapia intensiva de pacientes adultos

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ABSTRACT

Objective: To verify if the maximal inspiratory pressure values with 40 seconds occlusion time are greater than with the 20 seconds occlusion time, and the impacts on the following patient's physiological variables: respiratory rate, pulse oxygen saturation, heart rate and blood pressure, before and after the measurements.

Methods: This was a transversal prospective randomized study. Fifty-one patients underwent maximal inspiratory pressure measurement, measured by one single investigator. The manometer was calibrated before each measurement, and then connected to the adapter and this to the unidirectional valve inspiratory branch for 20 or 40 seconds.

Results: The values with 40 seconds occlusion (57.6 ± 23.4 cmH2O) were significantly higher than the measurements taken with 20 seconds occlusion (40.5 ± 23.4 cmH2O; p=0.0001). The variables changes between the before and after measurement respiratory and hemodynamic parameters monitoring showed: heart rate variation for the 20 seconds occlusion 5.13 ± 8.56 beats per minute and after 40 seconds occlusion 7.94 ± 12.05 beats per minute (p = 0.053), versus baseline. The mean blood pressure change for 20 seconds occlusion was 9.29 ± 13.35 mmHg and for 40 seconds occlusion 15.52 ± 2.91 mmHg (p=0.021). The oxygen saturation change for 20 seconds occlusion was 1.66 ± 12.66%, and for 40 seconds 4.21 ± 5.53% (p=0.0001). The respiratory rate change for 20 seconds occlusion was 6.68 ± 12.66 movements per minute and for 40 seconds 6.94 ± 6.01 (p=0.883).

Conclusions: The measurement of maximal inspiratory pressure using a longer occlusion (40 seconds) produced higher values, without triggering clinically significant stress according to the selected variables.

Keywords: Ventilator weaning; Respiratory muscles; Intensive care units

INTRODUCTION

Maximal inspiratory pressure (IPmax) is a simple and reproducible test, used to measure the inspiratory muscle strength reflecting the combination of force capacity generated by inspiratory muscle in a short almost-static contraction.[1,2]

Although IPmax continues to be used in severely ill patients as an overall respiratory muscles function indicator, it highly depends on several variables, which may be specifically difficult to control in the intensive care unit (ICU) settings.[3] Recent findings suggest that 40% of mechanically ventilated patients have a reduced IPmax during their artificially ventilated time.[4]

IPmax measuring has been used through an unidirectional valve in order to prevent results changes due to consciousness level, sedation or lack of motivation, all common features in ICU.[4] Although its reproducibility and accuracy are questioned, by the unidirectional valve method it was possible establishing a more reproducible form to reach higher IPmax values than with simple end-expiratory occlusion.[5-8]

The number of respiratory movements and occlusion time to observe are controversial. The recommendations range from one single respiratory movement to 20 seconds as minimum occlusion time.[8-12]

IPmax relevance for monitoring respiratory muscle training as well as predicting mechanic ventilated patients weaning failure has been well accepted, as it has low equipment costs and is an easy to perform test.[12]

A reliable IPmax evaluation, in conjunction with other findings, may predict mechanic ventilation (MV) weaning failure and consequently the need of respiratory muscle training. However, there is no uniformity on bed side methodology for measuring the inspiratory muscle strength in artificial airway non-cooperative patients.

Thus, this study aimed to verify if maximal inspiratory pressure values with 40 seconds occlusion time are greater that with 20 seconds occlusion and the impact on the patient's physiologic variables respiratory rate (RR), pulse oxygen saturation (SpO_2), heart rate (HR) and mean blood pressure (MBP) before and after the measurements.

METHODS

This study was conducted in male and female patients above 18 years-old, staying in a general ICU, all under ventilatory weaning, intubated, tracheostomized, or under spontaneous ventilation and tracheostomy disconnected for less than 48 hours from MV.

Patients with IPmax measurement contraindications, such as cranial hypertension, chest wall instability, bronchial-pleural or tracheal-esophageal fistulae, hemodynamic instability with mean blood pressure (MBP) < 70 mmHg even after volume resuscitation, alveolar hemorrhage, known coronary artery disease and upper airway leakage even after cuff hyperinsuflation, were excluded.

This was a transversal prospective randomized trial, in a sample of polytraumatized, clinical and surgical neurologic predominantly chronic patients, with stable no vasoactive drugs hemodynamics, no sedation, not cooperative, with Glasgow Coma Scale Score (GCSS) below 15, with an artificial airway, under MV weaning with support pressure ventilation (SPV) mode, 5 cmH_2O Positive End Expiratory Pressure (PEEP), inspired oxygen fraction (FiO2) ≤ 40%, or spontaneous ventilation (SV) with a T piece disconnected from MV for less than 48 hours.[13]

The measurements were always performed in the morning.[12] The patients were positioned with 45º head of bed elevation, underwent tracheal aspiration 10 minutes before the measurement, the cuff pressure was adjusted accordingly for no air leakage on lung auscultation. Next the patients were disconnected from MV to SV for at least 10 seconds, and the RR, SpO2, HR and MBP parameters were collected before and after measurements, divided in respiratory and hemodynamic variables. The measurement was performed by one single investigator, with the manometer calibrated before each measurement keeping the pointer on zero, and next connected to the adapter and this to the unidirectional valve inspiratory branch.[14]

The randomization was made by simple lottery, according to which was decided the initial airway occlusion time used for the subjects entering the trial. This random order of the initial times had a 15 minutes interval.

One single measurement was performed according to the randomization with each occlusion time in the fifty one non-cooperative neurological patients with GCSS < 15, as this is an unidirectional valve method used for patients who would not benefit from repeating the maneuver to obtain increased IPmax values, as patients with this profile would not benefit from learning.[13,15-17]

The data were collected with an analogical model MV-120 Instrumentation Industries manometer, with a 0 to 120 cmH_2O range, silicone pressure line, inspiratory and expiratory force adapter, adapter/reducer, a chronometer and an unidirectional valve. As maneuver interruption criteria were used the association of two or more of the following criteria: SpO2 ≤ 90%; RR ≥ 40 mpm, HR ≥ 140 bpm, MBP ≥ 120 mmHg.

Continuous variables were described as means and standard deviations. Categorical variables were expressed as percent. The t Student test was used for comparison of mean inspiratory pressures in the 20 and 40 seconds occlusion times, and the t pairwise test was used to compare the respiratory (RR and SpO2) and hemodynamic (MBP and HR) parameters changes before and after the measurements. The SPSS 12.0 (Statistical Package for Social Sciences) software was

used, and the significance level adopted was 5%. According to the Law 196/96, all evaluations were only conducted after consent of the immediate responsible for the subjects, as manifested by signing the Informed Consent Form clarifying the entire process and assuring data confidentiality. This project was approved by the Faculdade Adventista de Fisioterapia's Ethics Committee, approval opinion nr. 092/2008.

RESULTS

Fifty one patients were screened. The demographics are described on Table 1 and Chart 1. The 40 seconds occlusion IPmax values (IP40) were significantly higher than with the 20 seconds occlusion (IP20) as shown in Figure 1. The mean IPmax value with 20 seconds was 40.6 ± 23.4 cmH2O versus 57.6 ± 23.4 cmH2O for 40 seconds occlusion (p=0.0001).

Among the respiratory variables, the post-IP20 measurement RR was 29.2 ± 12.5 mpm versus 29.2 ± 7.6 mpm following IP40 (p=0.001). Mean post-IP20 SpO2 was 95.4 ±3# versus 93 ± 6.04% following IP40 (p=0.001).

Table 1 - Overall samples characteristics

Variables	Value
Gender	
Male	40 (78.4)
Female	11 (21.6)
Age (years)	43.5 ± 19.3
MV time (days)	11.0 ± 6.0
Characteristics	
Clinical	10 (19.6)
Surgical	41 (80.4)
Diagnosis	
Brain traumatic injury	28 (54.9)
Brain stroke	13 (25.5)
Polytrauma	10 (19.6)
Airway	
Tracheostomy	18 (35.3)
Orotracheal tube	33 (64.7)
Type of ventilation	
Assisted	47 (92.2)
Spontaneous	4 (7.8)
Support pressure	12.1 ± 3.9

MV – mechanic ventilation. Values expressed as number (%) or mean ± standard deviation.

Chart 1 - Individual sample demographics

Identification	Gender	Age	MV time	Characteristics	Diagnosis	Airway	Ventilation	SP level
1	F	18	1	Surgical	Polytrauma	OTT	Assisted	7
2	M	52	13	Surgical	BTI	TCT	Assisted	15
3	F	55	21	Surgical	Stroke	OTT	Assisted	12
4	M	23	21	Clinical	BTI	OTT	Assisted	10
5	F	47	7	Surgical	BTI	OTT	Assisted	14
6	F	22	5	Surgical	BTI	OTT	Assisted	7
7	M	45	7	Surgical	BTI	OTT	Assisted	18
8	M	30	5	Surgical	BTI	OTT	Assisted	7
9	F	25	10	Surgical	BTI	OTT	Assisted	12
10	F	62	10	Surgical	Polytrauma	OTT	Assisted	15
11	M	41	19	Surgical	Polytrauma	TCT	Assisted	12
12	M	35	14	Surgical	BTI	TCT	Assisted	10
13	M	31	8	Clinical	BTI	OTT	Assisted	10
14	M	50	8	Surgical	Polytrauma	OTT	Assisted	12
15	M	30	7	Surgical	BTI	OTT	Assisted	15
16	M	80	8	Surgical	Polytrauma	OTT	Assisted	7
17	F	30	5	Clinical	Stroke	OTT	Assisted	12
18	M	28	17	Surgical	BTI	TCT	Assisted	15
19	M	63	9	Surgical	BTI	OTT	Assisted	10
20	M	24	18	Clinical	BTI	TCT	Assisted	20
21	M	49	9	Surgical	BTI	OTT	Assisted	10
22	F	35	12	Clinical	Stroke	OTT	Assisted	12

Continued...

Chart 1 - Continuation

Identification	Gender	Age	MV time	Characteristics	Diagnosis	Airway	Ventilation	SP level
23	M	21	6	Surgical	Polytrauma	OTT	Assisted	15
24	M	49	20	Surgical	Stroke	TCT	Assisted	10
25	M	41	24	Surgical	Stroke	TCT	Assisted	10
26	M	57	8	Surgical	BTI	OTT	Assisted	10
27	M	32	11	Clinical	Polytrauma	OTT	Assisted	12
28	M	43	18	Surgical	Stroke	TCT	Assisted	12
29	M	76	26	Clinical	Polytrauma	TCT	Assisted	18
30	M	19	20	Clinical	BTI	TCT	Assisted	17
31	M	19	9	Surgical	Polytrauma	OTT	Assisted	10
32	F	34	8	Surgical	Polytrauma	OTT	Assisted	12
33	F	83	12	Surgical	BTI	OTT	Assisted	12
34	M	68	2	Surgical	Stroke	OTT	Assisted	20
35	F	64	9	Surgical	Stroke	OTT	Assisted	14
36	M	27	9	Surgical	BTI	OTT	Assisted	12
37	M	62	7	Surgical	Stroke	OTT	Assisted	20
38	M	83	10	Clinical	Stroke	TCT	Assisted	10
39	M	23	2	Surgical	BTI	TCT	Spontaneous	-
40	M	24	23	Surgical	BTI	TCT	Spontaneous	-
41	M	41	10	Surgical	Stroke	OTT	Assisted	12
42	M	32	5	Clinical	BTI	OTT	Assisted	10
43	M	57	8	Surgical	BTI	OTT	Assisted	7
44	M	90	5	Surgical	Stroke	TCT	Spontaneous	-
45	M	30	7	Surgical	BTI	OTT	Assisted	10
46	M	57	7	Surgical	Stroke	OTT	Assisted	15
47	M	27	5	Surgical	BTI	TCT	Assisted	15
48	M	43	23	Surgical	BTI	TCT	Assisted	15
49	M	43	12	Surgical	BTI	TCT	Assisted	12
50	M	31	11	Surgical	BTI	OTT	Assisted	7
51	M	67	19	Surgical	BTI	TCT	Spontaneous	-

MV – mechanic ventilation; SP – support pressure; F – female; M – male; BTI – brain traumatic injury; OTT – orotracheal tube; TCT – tracheostomy.

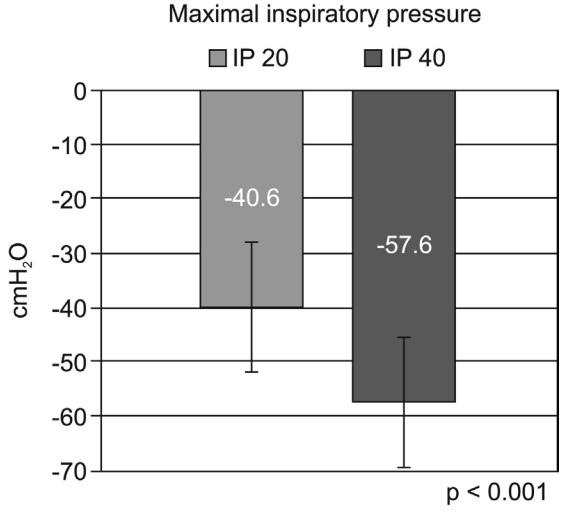

Figure 1 – IP20 and IP40 results.

Regarding hemodynamic variables, mean post-IP20 HR was 98.4 ± 18.5 bpm (p=0.001) and post-IP40 101.2 ± 19.7 (p=0.001). Post-IP20 MBP was 114.9 ± 15.4 (p=0.001), while post-IP40 MBP was 121.7 ± 21.2 (p=0.001). Table 2 shows the respiratory and hemodynamic impacts of the different IPmax measurements.

When the pre- and post-measurement hemodynamic and respiratory parameters changes (Δ) are compared, as shown in Table 2, an IP20 ΔHR = 5.1 ± 8.6 bpm was identified, and 7.9 ± 12.1 bpm for IP40 ΔHR versus baseline values (p=0.053). The MBP change was 9.3 ± 13.4 mmHg and IP40 Δ MBP was -15.5 ± 2.9 mmHg (p=0.021). IP20 ΔSpO2 was 1.7 ± 12.7% and for IP40 the Δ SpO2 was 4.2 ± 5.2% (p=0.0001). IP20 ΔRR was 6.7 ± 12.7 mpm, and IPmax ΔRR was 6.9 ± 6 mpm (p=0.883).

Table 2 – Maximal inspiratory pressure measurement respiratory and hemodynamic changes with range (Δ)

Physiological variables	IP 20*				IP 40**				
	Before	After	p value	Δ	Before	After	p value	Δ	Δ p value
RR	22.5 ± 6.7	29.2±12.5	0.001	6.7±12.7	22.2±6.5	29.2±7.6	0.001	7±6	0.0883
SpO2	97.1±1.4	97.1±1.4	0.001	1.7±12.7	97.2±1.2	93±6	0.001	4.2±5.5	0.0001
HR	93.2±16.2	98.4±18.5	0.001	5.2±8.6	93.2±17.1	101.2±19.7	0.001	7.9±12.1	0.053
MBP	105.6±14.3	114.9±15.4	0.001	9.3±13.6	106±15.6	121±21.2	0.001	15.5±2.9	0.021

IP – inspiratory pressure; Δ - range; RR – respiratory rate; SpO2 – pulse oxygen saturation; HR – heart rate; MBP – mean blood pressure. Results expressed as mean ± standard deviation. *Maximal inspiratory pressure measured with 20 seconds occlusion time. **Maximal inspiratory pressure measured with 40 seconds occlusion time.

DISCUSSION

Increased artificial airway occlusion time lead to increased IPmax values when the two different types of measurement in the studied subjects are compared. The IP40 measurement found a mean 57.6 ± 23.4 cmH2O value, versus 40.6 ± 23.4 cmH2O mean for IP20 measurement (p=0.0001).

Airway occlusion methods

A recent trial investigated the IPmax evaluation in thirty non-cooperative and under MV weaning patients using two occlusion times, 20 and 40 seconds, showing significant differences for the IP40 versus IP20 comparison (56.6 ± 23.3 versus 43.4 ± 24 cmH2O; p<0.001), agreeing with this trial results, reporting as the best IPmax evaluation for non-cooperative patients a 40 seconds occlusion.[14]

Another trial evaluated two occlusion methods in a heterogeneous 28 subjects population, either with or without consciousness level changes, under ventilatory weaning process, concluding that IP20 looks to be insufficient to measure the real IPmax in GCSS < 15 patients.[3] However, the measurement should have been performed in a more homogeneous patients population, such as in traumatic and non-traumatic, clinical and surgical neurological patients.

This study's sample was limited to traumatic brain injury (TBI), stroke and polytrama patients, also using the GCSS, differently from other authors who classified the patients as either alert or non-alert, rendering the real subject's cooperation level subjective.[8] It was assumed, based on previous studies, that a GCSS < 15 is characteristic of a non-cooperative patient.[3]

In a recent twenty three patients trial, IPmax values were compared with four different occlusion times (IPmax 20, 30, 45 and 60 seconds). The maneuver was repeated thrice, with five to ten minutes between measurements intervals.[9,10,15,16,18] IPmax differences were seen in the studied times (p=0.001) IP20 (29 ± 9.2); IP30 (34.4 ± 10); IP45 (41.9 ± 13.2); IP60 (46.8 ± 14.9); no statistically significant differences were found for the three IP60 measurements. Thus, the greatest IPmax value was found for a 60 seconds occlusion time, with no additional maneuvers needed for the maximal inspiratory pressure.

IPmax measurement effects

In this trial 40 seconds was selected as longest measurement time because this occlusion method impacts were not known so far, thus being necessary to know about eventual additional IPmax measurement stress for longer than 40 seconds occlusion.

A recent trial mentioned that patients were monitored regarding HR and SpO2, however pre- and post-measurement values were not recorded, rendering impossible to evaluate prolonged maneuver impacts, particularly at 40 seconds.[14]

The risks for this technique use include increased RR, HR and BP, and decreased SpO2, however, among the benefits can be mentioned being able to predict possible MV discontinuation failure and obtaining a parameter for muscle strength loss and gain in respiratory training subjects.

The role of hyperoxygenation

Although hyperoxygenation clinically minimizes desaturation effects, there is a physiological argument considering that it can lead to actual IPmax overestimation, being then necessary a trial comparing the IPmax values with and without previous FiO2 adjustment to 100%. It was recently identified a lower impact on SPO2 and increased occlusion time reached when submitting patients to hyperoxygenation, with

IPmax values improvement.[17] However, this option was not used in this trial, as it was considered to possibly influence the IPmax results.

Clinical and statistical changes analysis

This trial proposed to evaluate the impact of prolonged maneuver on respiratory and hemodynamic functions. When the HR, MBP, RR and SpO2 variables were compared after both occlusion times, no statistically significant post-measurement difference was found for HR and RR (p=0.053 and p=0.883, respectively), and a statistically significant impact was found for MBP and SpO2 (p=0.021 and p=0.0001, respectively).

As the absence of RR and HR variables impact, the SpO2 and MBP variables impact was not necessarily translated into clinical changes. We believe that tie IPmax measurement is safe, and can be performed using a longer occlusion time, however it is important to define validated clinical boundaries, if the maneuver needs to be withheld. Consonant with the literature data, considering as clinically significant 20% increase/decrease MBP values, or 10% increase of resting heart rate, and SpO2 drop to values below 90%,[18-21] this study found a mean change of IP40 HR of 7.84%, MBP 12.76% and SpO2 drop to 93%.

Thus, during IP40 measurement, no clinically significant impact was detected for the respiratory and hemodynamic variables, being their variations considered within the safety interval, not related with additional stress to the studied population. Nevertheless, we do not recommend airway occlusion longer than 40 seconds for IPmax measurement, and much less performing the maneuver without appropriate patient monitoring.

Study limitations

One limitation for this trial was not capturing the selected patients' severity score, and that they weren't necessarily under invasive MBP monitoring, which would provide more accurate information. Nevertheless, this trial has shown considerable and homogeneous sample when compared to other studies using smaller samples and evaluating diverse types of respiratory failure.

Perspective for mechanic ventilation weaning

Although IPmax measurement still has no clear correlation with mechanic ventilation weaning success or critical patients clinical outcome, it is believed that higher IPmax values may be associated with improved lung ventilation, airways clearance and outcomes in these subjects.

This trial didn't aim to evaluate neurological patients ventilatory weaning success or failure. This study has no sufficient power to detect superiority between the occlusion times, as no follow-up was performed regarding mechanic ventilation weaning outcome.

CONCLUSION

IPmax measurement with 40 seconds occlusion time has shown values greater than the traditional 20 seconds method, and, although the statistical significance found for some variables analyzed with both airway occlusion times, no clinically significant impact was found during IP40 measurement for these neurological patients; however, we highlight the importance of monitoring the hemodynamic and respiratory variables evaluated in this trial.

Further studies are necessary to confirm the feasibility of increased airway occlusion times for IPmax measurements, and how this evaluation is associated with ICU mechanic ventilated patients outcome.

RESUMO

Objetivo: Verificar se os valores de pressão inspiratória máxima com o tempo de oclusão de 40 (PI 40) segundos são maiores do que no tempo de oclusão de 20s (PI 20) e as repercussões apresentadas pelo paciente através das variáveis fisiológicas freqüência respiratória, saturação de pulso de oxigênio, freqüência cardíaca e pressão arterial antes e após as medidas.

Métodos: Estudo transversal prospectivo randomizado. Foram selecionados cinqüenta e um pacientes para realização da medida de pressão inspiratória máxima, mensurada por um único investigador, com calibração do manovacuômetro antes de cada aferição, conectado em seguida ao adaptador e este ao ramo inspiratório da válvula unidirecional durante 20 e 40 segundos.

Resultados: Os valores da PI 40 (57,6 ± 23,4 cmH2O) foram significativamente superiores às medidas realizadas durante um período de 20 segundos (40,5 ± 23,4cmH2O; p=0,0001). As variações (Δ) das medidas antes e após monitoração dos parâmetros respiratórios e hemodinâmicos reportaram um Δ freqüência cardíaca PI 20 = 5,13 ± 8,56 bpm e 7,94 ± 12,05 bpm (p = 0,053) para a medida de Δ freqüência cardíaca PI 40 em relação a seus valores basais. O Δ pressão arterial média PI 20 foi de 9,29 ± 13,35 mmHg e o Δ pressão

arterial média PI 40 foi de 15,52 ± 2,91 mmHg (p = 0,021). O Δ saturação de oxigênio para PI 20 1,66 ± 12,66%, e Δ saturação de oxigênio para PI 40 4,21 ± 5,53% (p = 0,0001). O Δ freqüência respiratória para PI 20 6,68 ± 12,66 ipm, e Δ freqüência respiratória PI 40 foi 6,94 ± 6,01 ipm (p= 0,883).

Conclusões: A mensuração da pressão inspiratória máxima utilizando uma oclusão superior (40s) produziu maiores valores quanto à pressão inspiratória máxima encontrada, sem desencadear estresse clinicamente significativos nas variáveis selecionadas.

Descritores: Desmame da ventilação mecânica; Músculos respiratórios; Unidades de terapia intensiva

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