ISSN 2220-3141 (online)

World Journal of *Critical Care Medicine*

World J Crit Care Med 2018 February 4; 7(1): 1-30

Published by Baishideng Publishing Group Inc

WJCCM World Journal of Critical Care Medicine

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Editorial Board Member of *World Journal of Critical Care Medicine*, Ayman A Yousef, MD, Assistant Professor, Department of Anesthesia, Tanta University Hospitals, Tanta 31527, Egypt

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INDEXING/ABSTRACTING

World Journal of Critical Care Medicine is now indexed in PubMed, PubMed Central.

NAME OF JOURNAL
World Journal of Critical Care Medicine

ISSN
ISSN 2220-3141 (online)

LAUNCH DATE
February 4, 2012

FREQUENCY
Quarterly

EDITORIAL OFFICE
Xiu-Xia Song, Director
World Journal of Critical Care Medicine
Baishideng Publishing Group Inc
7901 Stoneridge Drive, Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-2238242
Fax: +1-925-2238243
E-mail: editorialoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
http://www.wjgnet.com

PUBLISHER
Baishideng Publishing Group Inc
7901 Stoneridge Drive,
Suite 501, Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.f6publishing.com/helpdesk
http://www.wjgnet.com

PUBLICATION DATE
February 4, 2018

INSTRUCTIONS TO AUTHORS
http://www.wjgnet.com/bpg/gerinfo/204

ONLINE SUBMISSION
http://www.f6publishing.com

World Journal of Critical Care Medicine

Submit a Manuscript: http://www.f6publishing.com

World J Crit Care Med 2018 February 4; 7(1): 24-30

DOI: 10.5492/wjccm.v7.i1.24

ISSN 2220-3141 (online)

SYSTEMATIC REVIEWS

Respiratory mechanics, ventilator-associated pneumonia and outcomes in intensive care unit

Kelser de Souza Kock, Rosemeri Maurici

Kelser de Souza Kock, Department of Physiotherapy, University of South of Santa Catarina, Tubarão, SC 88704-001, Brazil

Rosemeri Maurici, Graduate Program in Medical Sciences, Federal University of Santa Catarina, Florianópolis, SC 88700-000, Brazil

ORCID number: Kelser de Souza Kock (0000-0002-0117-6142); Rosemeri Maurici (0000-0001-9627-2112).

Author contributions: Kock KS performed the data collect, statistical analysis and wrote the mansucript; Maurici R performed the revision and editing the manuscript.

Conflict-of-interest statement: There is no conflict-of-interest.

Data sharing statement: No additional data is available.

Manuscript source: Unsolicited manuscript

Correspondence to: Kelser de Souza Kock, MSc, Department of Physiotherapy, University of South of Santa Catarina, José Acácio Moreira street, number 787, Tubarão, SC 88704-001, Brazil. kelserkock@yahoo.com.br
Telephone: +55-48-999969811

Received: August 28, 2017
Peer-review started: August 29, 2017
First decision: September 25, 2017
Revised: November 5, 2017
Accepted: December 3, 2017
Article in press: December 3, 2017
Published online: February 4, 2018

Abstract

AIM

To evaluate the predictive capability of respiratory mechanics for the development of ventilator-associated pneumonia (VAP) and mortality in the intensive care unit (ICU) of a hospital in southern Brazil.

METHODS

A cohort study was conducted between, involving a sample of 120 individuals. Static measurements of compliance and resistance of the respiratory system in pressure-controlled ventilation (PCV) and volume-controlled ventilation (VCV) modes in the 1st and 5th days of hospitalization were performed to monitor respiratory mechanics. The severity of the patients' illness was quantified by the Acute Physiology and Chronic Health Evaluation Ⅱ (APACHE Ⅱ). The diagnosis of VAP was made based on clinical, radiological and laboratory parameters.

RESULTS

The significant associations found for the development of VAP were APACHE Ⅱ scores above the average (P = 0.016), duration of MV (P = 0.001) and ICU length of stay above the average (P = 0.003), male gender (P = 0.004), and worsening of respiratory resistance in PCV mode (P = 0.010). Age above the average (P < 0.001), low level of oxygenation on day 1 (P = 0.003) and day 5 (P = 0.004) and low lung compliance during VCV on day 1 (P = 0.032) were associated with death as the outcome.

CONCLUSION

The worsening of airway resistance in PCV mode indicated the possibility of early diagnosis of VAP. Low lung compliance during VCV and low oxygenation index were death-related prognostic indicators.

Key words: Respiratory mechanics; Respiratory tract infection; Ventilator-associated pneumonia

Core tip: The results show that the respiratory function is a prognostic measure, and is strongly associated with mortality. Low oxygen and low lung compliance during volume-controlled ventilation demonstrate this fact. Worsening of respiratory system resistance during pressure-controlled ventilation, associated with the development of ventilator-associated pneumonia, indicates the possibility of early diagnosis. Based on this assumption, this procedure should be performed routinely in the intensive care unit environment, providing the intensive care physician and the physiotherapist with additional prognosis and diagnosis variables, in addition to the clinical, laboratory and radiological data.

Kock KS, Maurici R. Respiratory mechanics, ventilator-associated pneumonia and outcomes in intensive care unit. *World J Crit Care Med* 2018; 7(1): 24-30 Available from: URL: http://www.wjgnet.com/2220-3141/full/v7/i1/24.htm DOI: http://dx.doi.org/10.5492/wjccm.v7.i1.24

INTRODUCTION

Factors influencing the outcomes in intensive care unit (ICU) enable behaviors that can benefit the patient and reduce hospital costs[1,2]. Monitoring of respiratory mechanics in the admission of patients may provide an additional parameter for the monitoring of cases with possible epidemiological implications[3]. Invasive ventilatory support is a resource frequently used in extremely critical care, either to rescue breathing in patients unable to maintain the ventilatory demand, or as a strategy for energy saving in seriously ill patients[4]. Knowledge about respiratory mechanics may facilitate the detection of changes in the respiratory status of the patient and enable appropriate adjustment in ventilatory parameters, as well as support an appropriate therapeutic intervention to improve his or her clinical condition[5,6].

Few studies use these variables as prognostic measures in ICU[7]. The main applications of monitoring respiratory mechanics are performed on well-established cases, such as in patients with obstructive lung disease[8] and in patients with acute respiratory distress syndrome (ARDS)[9]. Some studies discuss the importance of these measures in patients with pulmonary fibrosis[10] or with the human immunodeficiency virus (HIV) infection and pneumonia[11].

The measurements of respiratory mechanics most frequently used are compliance and resistance of the respiratory system. Compliance is associated with distensibility of the respiratory system, which is resulting from the tidal volume variation divided by the peak inspiratory pressure. Resistance is related to the conduction of air, obtained mathematically from the variation between the peak and plateau pressures divided by the inspiratory airflow[12].

Ventilator-associated pneumonia (VAP) is the most common infection in ICU. This pulmonary condition may change the respiratory mechanics. Beyond the importance of the bundles of care for the prevention of VAP[13], information of compliance and resistance of respiratory system can provide additional data for an early diagnosis. The aim of this study was to assess the risk of changes in respiratory mechanics for determination of outcomes: development of VAP, and mortality in ICU.

MATERIALS AND METHODS

A cohort study was performed on adults in the intensive care unit of the of the Hospital Nossa Senhora da Conceição, located in Tubarão, State of Santa Catarina, Brazil. Individuals hospitalized between February and September 2013 who required invasive ventilatory support and whose family signed the informed consent were selected. The study was approved by the Human Research Ethics Committee of the University of Southern Santa Catarina (number 12.460.4.08.Ⅲ).

As this is a study of diagnostic and prognostic accuracy, the sample size was dimensioned for a prevalence of mortality[14] and VAP[15] of 20% (P = 0.2), with a 12% error (e = 0.12) in the 95% confidence interval ($Z_{\alpha/2}$ = 1.96). Sensitivity was defined 90% (Sens = 0.9). The equation[16] used is described below:

$$n_{sens} = \frac{(Z_{\alpha/2})^2\ Sens.(1\text{-}Sens)}{e^2.P} \approx 120$$

The following subjects were excluded from the study: Patients who were hospitalized in the ICU for cardiac surgery, those who developed pneumonia, died, or were extubated within 48 h of the onset of mechanical ventilation, those who were reintubated and those whose cause of orotracheal intubation was respiratory infection. The patients who were transferred to another ICU were excluded as well.

The following procedures were performed for the data collection: Day 1 (D1) - First 24 h of mechanical ventilation. APACHE Ⅱ[17] scoring, assessment of oxygenation index obtained from the PaO_2/FiO_2 ratio[18], and assessment of the respiratory system compliance and resistance were performed. The patients should score 5-6 in the Ramsay sedation scale[19] for measuring airflow compliance and resistance. Respiratory mechanic was measured in volume-controlled ventilation (VCV) and pressure-controlled ventilation (PCV)[20]. The equations for calculating respiratory mechanics were these:

Volume Control Ventilation (VCV)[20]

$$C_{RS} = \frac{V_T}{P_{Plat} - PEEP} \qquad R_{RS} = \frac{P_{Peak} - P_{Plat}}{F}$$

Pressure Control Ventilation (PCV)[16]

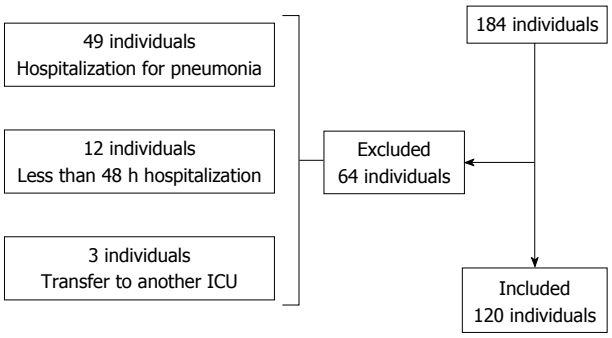

Figure 1 Flow chart of sample characterization.

Table 1 Characteristics of the sample

Sample characteristics (n = 120)	Results
Age (yr)	
Mean ± SD	58.5 ± 19.4
Minimum-maximum	15-91
Gender *n* (%)	
Male	69 (57.5)
Female	51 (42.5)
APACHE Ⅱ (score)	
Mean ± SD	27.4 ± 6.7
Minimum-maximum	8-47
Risk of mortality (%)-APACHE Ⅱ	
Mean ± SD	61.8 ± 7.3
Admission diagnoses *n* (%)	
Diseases of the circulatory system	43 (35.8)
Diseases of the respiratory system	15 (12.5)
Lesions, poisoning and other consequences of external causes	14 (11.7)
Gastrointestinal diseases	8 (6.7)
Unclassified signs and symptoms	8 (6.7)
Diseases of the genitourinary system	7 (5.8)
Neoplasia	4 (3.3)
Nervous system disorders	4 (3.3)
Infectious and parasitic diseases	3 (2.5)
Endocrine, nutritional and metabolic diseases	3 (2.5)
Other	11 (9.2)
Mechanical ventilators n (%)	
[1]Servo S	89 (74.2)
[1]Servo 900	203 (16.7)
[1]Dixtal	11 (9.2)

[1]Source: Prepared by the author, 2013.

$$C_{RS} = \frac{V_T}{P_{Insp} - PEEP} \qquad R_{RS} = \frac{P_{Insp} - PEEP}{F_{max}^{1,75}}$$

C_{RS}: Respiratory system compliance (mL/cmH_2O); R_{RS}: Respiratory system resistance (cmH_2O/L/s); PEEP: Positive end-expiratory pressure (cmH_2O); P_{Insp}: Inspiratory pressure (cmH_2O); P_{peak}: Peak inspiratory pressure (cmH_2O); P_{plat}: Plateau pressure (cmH_2O); V_T: Tidal volume (mL); F: Forced inspiratory flow (L/s); F_{max}: Peak inspiratory flow (L/s).

Day 5 (D5) - Assessment of the respiratory system compliance and resistance was performed as described above. If the patient were in the ventilatory weaning process, this measure would not be collected.

Patients were monitored until their discharge from the ICU or death. The duration of mechanical ventilation and length of ICU stay were taken into account, until the emergence of at least one of those outcomes.

VAP was diagnosed by the emergence of new or progressive pulmonary infiltrate on the chest X-Ray, associated with signs and laboratory alterations, such as fever (> 38 ℃), leukocytosis (> 10000/mm^3) or leukopenia (< 4000/mm^3), and purulent tracheal secretions[21].

Early VAP was performed when it was diagnosed within the first 5 d. Late VAP was considered when the diagnosis occurred after the sixth day[15].

Statistical analysis

Data were stored in a database using a Microsoft Excell® software, which was exported to SPSS® Statistics 20.0. They were presented using absolute numbers and percentages, and measures of central tendency and dispersion. The cutoff point for normal respiratory compliance and resistance was defined as the means obtained from the results.

The analysis of numerical data was performed primarily by the Kolmogorov-Smirnov test for normality. The results with normal distribution were compared using Student's *t*-test, and the non-normal distribution results by using the Mann-Whitney test[22]. The Chi-square test was used for categorical data analysis. Variable comparisons were made in relation to the VAP outcomes, mortality, ICU stay and duration of mechanical ventilation. The relative risk was estimated, by univariate analysis, for variables with statistical association. The confidence interval was set at 95% and a $P < 0.05$ was considered statistically significant.

Measurements of the oxygenation index and respiratory mechanics were performed by analyzing the worsening or improvement in these variables between D1 and D5.

A higher airflow resistance in D1 than in D5 was considered a better state. Reversely, a lower airflow resistance, a worse result.

RESULTS

A total of 184 patients who were hospitalized in the ICU of the Hospital Nossa Senhora da Conceição (Tubarão, State of Santa Catarina, Brazil) between February and September 2013 were consecutively monitored (Figure 1).

According to the selection criteria, 120 patients were allocated to participate in the study. Table 1 describes the general characteristics of the sample.

Oxygenation index and respiratory mechanics on days 1 and 5 are shown in Table 2. On the 5th day, only 77 of the 120 patients were monitored, because they were either extubated, weaned from mechanical ventilation, or had died by then.

The incidence of VAP was 31.8% (38 cases), with an infection density of 24/1000 d. The 38 cases of VAP, 19 (50%) were of early 19 (50%) were late. The overall mortality rate was 62 cases (51.7%). The mean length of stay in ICU was 15.2 ± 11.1 d and mean duration of mechanical ventilation was 13.1 ± 10.6 d.

Table 2 Respiratory mechanics and oxygenation index on the 1st and 5th day

Oxygenation index Respiratory mechanics	Mean ± SD	Minimum-maximum
1st day (n = 120)		
PaO_2/FiO_2 (mmHg)	236.0 ± 97.6	47.0-465.7
Compliance-VCV (mL/cm H_2O)	40.9 ± 12.8	15.0-88.0
Resistance-VCV (cm H_2O/L/s)	13.2 ± 4.9	4.1-28.6
Compliance-PCV (mL/cm H_2O)	35.0 ± 10.0	15.0-62.0
Resistance-PCV (cm H_2O/L/s)	27.3 ± 16.2	9.1-131.1
5th day (n = 77)		
PaO_2/FiO_2 (mmHg)	241.7 ± 88.7	58.0-445.0
Compliance-VCV (mL/cm H_2O)	39.7 ± 13.2	18.0-83.0
Resistance-VCV (cm H_2O/L/s)	13.8 ± 6.0	5.3-43.0
Compliance-PCV (mL/cm H_2O)	32.9 ± 9.3	13.5-52.5
Resistance-PCV (cm H_2O/L/s)	26.4 ± 11.8	6.2-73.5

Source: Prepared by the author, 2013. VCV: Volume-controlled ventilation; PCV: Pressure-controlled ventilation.

Table 3 Numeric variables and ventilator-associated pneumonia

Variables	VAP		*P* value
	Yes	No	
APACHE II[1]	29.2 ± 5.6	26.5 ± 7.1	0.026
Age (yr)	57.1 ± 19.1	59.2 ± 19.6	0.565
1st day (n = 120)			
PaO_2/FiO_2 (mmHg)[1]	232.3 ± 79.9	237.8 ± 105.2	0.756
Compliance-VCV (mL/cmH_2O)	43.1 ± 14.9	39.8 ± 11.6	0.365
Resistance-VCV (cmH_2O/L/s)	13.7 ± 5.0	13.0 ± 4.8	0.594
Compliance-PCV (mL/cmH_2O)[1]	34.8 ± 10.4	35.1 ± 9.8	0.879
Resistance-PCV (cmH_2O/L/s)	23.6 ± 10.3	29.0 ± 18.1	0.114
5th day (n = 77)			
PaO_2/FiO_2 (mmHg)[1]	244.1 ± 94.1	240.2 ± 86.1	0.850
Compliance-VCV (mL/cmH_2O)	43.3 ± 14.0	37.6 ± 12.3	0.092
Resistance-VCV (cmH_2O/L/s)	13.9 ± 6.8	13.8 ± 5.5	0.996
Compliance-PCV (mL/cmH_2O)[1]	33.6 ± 8.9	32.5 ± 9.6	0.606
Resistance-PCV (cmH_2O/L/s)	27.1 ± 11.7	25.9 ± 12.0	0.777
(n = 120)			
Duration of MV (d)	18.4 ± 14.9	10.7 ± 6.8	0.001
Length of stay in ICU (d)	20.4 ± 15.3	12.8 ± 7.6	0.003

Mann-Whitney *U*-test; [1]Student's *t*-test. Source: Prepared by the author, 2013. VAP: Ventilator-associated pneumonia; VCV: Volume-controlled ventilation; PCV: Pressure-controlled ventilation; MV: Mechanical ventilation; ICU: Intensive care unit.

Tables 3 and 4 shows the numeric variables compared with VAP rates and outcomes: Mortality.

Table 5 presents the relative risk estimate for the variables that demonstrated statistical association with VAP and the outcomes.

DISCUSSION

The general characteristics of the sample were similar to those of other studies on ICU, *i.e.*, most individuals were male and the mean age exceeded middle age[14,23,24].

Among the surveyed patients, the severity of disease classified by the APACHE II was considered relatively high. A research carried out by Wunsch *et al*[14] analyzed the clinical and epidemiological characteristics of over 170000 patients from 160 ICUs in England and 137 ICUs in the United States. In the United States, the mean APACHE II score was 15.3 ± 8, and for mechanically ventilated subjects, the score was 20.1 ± 8.9. In England, these scores were significantly higher, reaching 20.5 ± 8.5 in the APACHE II score and 22.3 ± 8.2 for individuals undergoing artificial respiration.

A study conducted by Matic *et al*[25] assessed the influence of the APACHE II score on the selection of the mechanical invasive or non-invasive ventilatory support. The median APACHE II score was 24 in the group that received non-invasive mechanical ventilation, and 26 in the group that required invasive support. These data corroborate the findings of the present study, despite the fact that higher APACHE II scores indicate a more severe clinical condition in patients requiring invasive mechanical ventilatory support. However, the disease severity is related to the characteristics of each ICU, and comorbidities may influence the score, and consequently, the outcomes[26].

With respect to the most common causes of hospitalization in the ICU, the results of this study are in line with the research carried out by Wunsch *et al*[14], in which the main reasons were of cardiac origin (44.6% in the United States and 27.1% in England), followed by respiratory (20.2% in the United States and 26.3% in England), neurological (19, 1% in the United States. and 24.1% in England) and gastrointestinal (9.5% in the United States and 10.1% in England) causes. These results may differ according to the characteristics of each ICU[27,28].

The length of stay in the ICU and duration of MV were relatively high. According to a review study by Elliott[29], the length of stay for all patient profiles can vary from 2 to 13 d, according to the ICU and the severity of cases. A study by Esteban *et al*[30] that analyzed the characteristics and outcomes of adult patients requiring mechanical ventilation indicated an average length of stay in the ICU and duration of MV of 13.7 and 7.2 d, respectively. A study by Matic *et al*[25], also in mechanically ventilated patients, found an average duration in MV of 7 d, and length of stay in ICU of 8.5 d. A Brazilian multicenter study sample consisting of 775 adult patients from 45 ICUs showed that the average length of stay in ICU among subjects requiring only non-invasive ventilation was 7 d. Those who required invasive ventilatory support stayed for 13 d on average[31].

The data regarding the incidence of VAP in the present study were similar to those found in the literature. A review conducted by Joseph *et al*[15] demonstrated that the incidence can vary from 6% to 52%. The density of VAP infection described in the systematic review by Arabi *et al*[32] may vary from 10 episodes per 1000 ventilator days, such as in Thailand and Columbia, to 41.7 episodes per 1000 ventilator days in a cancer ICU in Brazil.

By comparing the significant associations of the variables for the development of VAP, it was observed that the APACHE II was a predictor, indicating that

Table 4 Numeric variables and death

Variables	Outcome		*P* value
	High	Death	
APACHE Ⅱ[1]	27.0 ± 7.6	27.7 ± 5.8	0.606
Age (yr)	51.1 ± 19.9	65.4 ± 16.1	< 0.001
1st day (n = 120)			
PaO_2/FiO_2 (mmHg)[1]	263.1 ± 100.9	210.7 ± 87.8	0.003
Compliance-VCV (mL/cm H_2O)	43.5 ± 12.5	38.4 ± 12.6	0.015
Resistance-VCV (cm H_2O/L/s)	13.3 ± 4.3	13.2 ± 5.4	0.935
Compliance-PCV (mL/cm H_2O)[1]	36.6 ± 9.8	33.6 ± 9.9	0.103
Resistance-PCV (cm H_2O/L/s)	25.0 ± 10.5	29.4 ± 20.0	0.416
5th day (n = 77)			
PaO_2/FiO_2 (mmHg)[1]	268.8 ± 81.9	214.7 ± 87.9	0.004
Compliance-VCV (mL/cm H_2O)	40.7 ± 12.7	38.7 ± 13.7	0.356
Resistance-VCV (cm H_2O/L/s)	14.2 ± 5.0	13.5 ± 6.9	0.22
Compliance-PCV (mL/cm H_2O)[1]	34.1 ± 9.4	31.8 ± 9.1	0.282
Resistance-PCV (cm H_2O/L/s) (n = 120)	25.7 ± 10.8	27.1 ± 12.9	0.76
Duration of MV (d)	14.5 ± 12.4	11.9 ± 8.6	0.212
Length of stay in ICU (d)	18.3 ± 12.5	12.4 ± 8.9	< 0.001

Mann-Whitney *U*-test; [1]Student's *t*-test. Source: Prepared by the author, 2013. VCV: Volume-controlled ventilation; PCV: Pressure-controlled ventilation; MV: Mechanical ventilation; ICU: Intensive care unit.

Table 5 Relative risk for ventilator-associated pneumonia and outcomes

Variables	RR	95%CI	*P* value
VAP			
APACHE II above the average	1.62	1.03-2.55	0.016
Male gender	1.56	1.18-2.08	0.004
Resistance worsening-PCV	1.85	1.16-2.94	0.01
Outcome: Death			
Age above the average	2.08	1.34-3.23	0.001
Compliance-VCV below average on 1st day	1.49	1.00-2.21	0.032
ICU stay below the average	2.05	1.28-3.28	0.001

Source: Prepared by the author, 2013. VAP: Ventilator-associated pneumonia; VCV: Volume-controlled ventilation; PCV: Pressure-controlled ventilation; ICU: Intensive care unit.

severe disease in ICU admission favors the occurrence of VAP. Other studies show no association; however, they describe that higher APACHE Ⅱ scores are related to higher mortality when applied at the time of VAP diagnosis[33,34].

A longer ICU stay and VM duration are also associated with VAP as demonstrated in this study, which is commonly presented in other works as well. Guimarães *et al*[35] evaluated 278 patients in a Brazilian university hospital, and reported a significant difference between the group with and without VAP, having stayed in the ICU for 14 and 5 d, respectively. Patients with spinal cord injury who require prolonged mechanical ventilation also had a higher incidence of VAP due to the increased length of ICU stay and MV dependence[36].

As evidenced in this study, the risk for the development of VAP is higher in men than women. According to Tejerina *et al*[37], 2897 patients from 361 ICUs were surveyed in 20 countries, in which it was shown that men have a relative risk of 1.3 for the occurrence of VAP compared with women.

Worsening resistance during PCV was related to VAP, possibly indicating increased airway inflammation and/or an increase in bronchopulmonary secretions, which is consistent with the pathophysiological mechanism of respiratory infection[21]. A worsening of lung compliance in subjects who developed VAP was also expected, but it did not occur. A study by Lorx *et al*[38] analyzed patients admitted to the ICU because of community-acquired pneumonia stratified into mild and severe conditions. Using low frequency forced oscillometry technique, it was observed that elastance, which is inversely proportional to compliance, was significantly higher in patients with severe pneumonia compared with those who had mild pneumonia. This evidence demonstrates the restrictive aspect of pneumonia, which was not found in the present study.

Monitoring of respiratory mechanics can assist the intensive care physician to detect early changes in lung function, associating them with the evolution of the ventilation status, and present scores associated with increased risk of mortality and VAP development. In addition, monitoring of mechanical breathing is performed at the bedside, does not involve patient transport, and has no financial cost to be implemented.

The results of the respiratory mechanics of the present study demonstrated a lower compliance and a higher resistance than the predicted values[3,6,12]. This may demonstrate a reduction in lung function of the participants. Advanced age was statistically associated with death as the outcome, which was also observed in other studies[23,30]. Low levels of oxygenation in the 1st and 5th days was also related to mortality, which corroborates the study by Eastwood *et al*[39] and de Jonge *et al*[40] that found an association between low levels of oxygenation in the first 24 h and mortality rates in their retrospective observational studies. Low pulmonary compliance during VCV on day 1 also indicated a prediction of mortality in individuals with low pulmonary distensibility. A study by Matić *et al*[7] monitored the static pulmonary compliance with intraesophageal balloon before intubation. It was shown that poor lung compliance was associated with high mortality rates.

It was expected that the incidence of VAP and higher APACHE Ⅱ scores were associated with mortality, which was not observed. Generally, VAP is associated with higher mortality rates[15]; however, Tejerina *et al*[37] found no significant differences between the groups with and without VAP, with an incidence of 38.1% and 37.9%, respectively.

The limitation of this study was the monitoring of respiratory mechanics with sedated patients and not with neuromuscular block. This may have a small influence on the results.

In conclusion, monitoring of the mechanical aspects of lung function is already commonly used in well-established groups with chronic obstructive pulmonary disease and ARDS. It is a simple procedure performed at the bedside, without any physical damage and

no additional cost. Based on this assumption, this procedure should be performed routinely in the ICU environment, providing the intensive care physician and the physiotherapist with additional prognosis and diagnosis variables, in addition to the clinical, laboratory and radiological data.

The results show that the respiratory function is a prognostic measure, and is strongly associated with mortality. Low oxygen and low lung compliance during VCV demonstrate this fact. Worsening of respiratory system resistance during PCV, associated with the development of VAP, indicates the possibility of early diagnosis.

ARTICLE HIGHLIGHTS

Research background

The measurements of respiratory mechanics most frequently used are compliance and resistance of the respiratory system. Compliance is associated with distensibility of the respiratory system, which is resulting from the tidal volume variation divided by the peak inspiratory pressure. Resistance is related to the conduction of air, obtained mathematically from the variation between the peak and plateau pressures divided by the inspiratory airflow.

Research motivation

The aim is evaluate the predictive capability of respiratory mechanics for the development of VAP and mortality in the intensive care unit (ICU) of a hospital in southern Brazil.

Research objectives

Respiratory mechanics, ventilator-associated pneumonia.

Research methods

A cohort study was conducted between, involving a sample of 120 individuals. Static measurements of compliance and resistance of the respiratory system in pressure-controlled ventilation (PCV) and volume-controlled ventilation (VCV) modes in the 1st and 5th days of hospitalization were performed to monitor respiratory mechanics. The severity of the patients' illness was quantified by the Acute Physiology and Chronic Health Evaluation Ⅱ (APACHE Ⅱ). The diagnosis of VAP was made based on clinical, radiological and laboratory parameters.

Research results

The significant associations found for the development of VAP were APACHE Ⅱ scores above the average (P = 0.016), duration of MV (P = 0.001) and ICU length of stay above the average (P = 0.003), male gender (P = 0.004), and worsening of respiratory resistance in PCV mode (P = 0.010). Age above the average (P < 0.001), low level of oxygenation on day 1 (P = 0.003) and day 5 (P = 0.004) and low lung compliance during VCV on day 1 (P = 0.032) were associated with death as the outcome.

Research conclusions

The worsening of airway resistance in PCV mode indicated the possibility of early diagnosis of VAP. Low lung compliance during VCV and low oxygenation index were death-related prognostic indicators.

Research perspectives

The results show that the respiratory function is a prognostic measure, and is strongly associated with mortality.

REFERENCES

1 **Nguyen YL**, Wunsch H, Angus DC. Critical care: the impact of organization and management on outcomes. *Curr Opin Crit Care* 2010; **16**: 487-492 [PMID: 20689418 DOI: 10.1097/MCC.0b013e32833d9180]

2 **Rubenfeld GD**, Angus DC, Pinsky MR, Curtis JR, Connors AF Jr, Bernard GR. Outcomes research in critical care: results of the American Thoracic Society Critical Care Assembly Workshop on Outcomes Research. The Members of the Outcomes Research Workshop. *Am J Respir Crit Care Med* 1999; **160**: 358-367 [PMID: 10390426 DOI: 10.1164/ajrccm.160.1.9807118]

3 **Henderson WR**, Sheel AW. Pulmonary mechanics during mechanical ventilation. *Respir Physiol Neurobiol* 2012; **180**: 162-172 [PMID: 22154694 DOI: 10.1016/j.resp.2011.11.014]

4 **Hamed HMF**, Ibrahim HG, Khater YH, Aziz ES. Ventilation and ventilators in the ICU: What very intensivist must know. *Curr Anaesth Crit Care* 2006; **17**: 77-83

5 **Polak AG**. Analysis of multiple linear regression algorithms used for respiratory mechanics monitoring during artificial ventilation. *Comput Methods Programs Biomed* 2011; **101**: 126-134 [PMID: 20822825 DOI: 10.1016/j.cmpb.2010.08.001]

6 **Lucangelo U**, Bernabé F, Blanch L. Respiratory mechanics derived from signals in the ventilator circuit. *Respir Care* 2005; **50**: 55-65; discussion 65-67 [PMID: 15636645]

7 **Matić I**, Pavicić F, Sakić-Zdravcević K, Danić D, Jurjević M. Pulmonary compliance values provide prognosis in mechanically ventilated patients--a randomized prospective study. *Coll Antropol* 2007; **31**: 829-836 [PMID: 18041396]

8 **Dhand R**. Ventilator graphics and respiratory mechanics in the patient with obstructive lung disease. *Respir Care* 2005; **50**: 246-261; discussion 259-261 [PMID: 15691394]

9 **Koutsoukou A**, Perraki H, Orfanos SE, Koulouris NG, Tromaropoulos A, Sotiropoulou C, Roussos C. History of mechanical ventilation may affect respiratory mechanics evolution in acute respiratory distress syndrome. *J Crit Care* 2009; **24**: 626.e1-626.e6 [PMID: 19427758 DOI: 10.1016/j.jcrc.2009.02.003]

10 **Nava S**, Rubini F. Lung and chest wall mechanics in ventilated patients with end stage idiopathic pulmonary fibrosis. *Thorax* 1999; **54**: 390-395 [PMID: 10212101 DOI: 10.1136/thx.54.5.390]

11 **D'Angelo E**, Calderini E, Robatto FM, Puccio P, Milic-Emili J. Lung and chest wall mechanics in patients with acquired immunodeficiency syndrome and severe Pneumocystis carinii pneumonia. *Eur Respir J* 1997; **10**: 2343-2350 [PMID: 9387963 DOI: 10.1183/09031936.97.10102343]

12 **Jubran A**. Monitoring patient mechanics during mechanical ventilation. *Crit Care Clin* 1998; **14**: 629-653 [PMID: 9891631 DOI: 10.1016/S0749-0704(05)70024-5]

13 **Hellyer TP**, Ewan V, Wilson P, Simpson AJ. The Intensive Care Society recommended bundle of interventions for the prevention of ventilator-associated pneumonia. *J Intensive Care Soc* 2016; **17**: 238-243

14 **Wunsch H**, Angus DC, Harrison DA, Linde-Zwirble WT, Rowan KM. Comparison of medical admissions to intensive care units in the United States and United Kingdom. *Am J Respir Crit Care Med* 2011; **183**: 1666-1673 [PMID: 21471089 DOI: 10.1164/rccm.201012-1961OC]

15 **Joseph NM**, Sistla S, Dutta TK, Badhe AS, Parija SC. Ventilator-associated pneumonia: a review. *Eur J Intern Med* 2010; **21**: 360-368 [PMID: 20816584 DOI: 10.1016/j.ejim.2010.07.006]

16 **Hajian-Tilaki K**. Sample size estimation in diagnostic test studies of biomedical informatics. *J Biomed Inform* 2014; **48**: 193-204 [PMID: 24582925 DOI: 10.1016/j.jbi.2014.02.013]

17 **Knaus WA**, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. *Crit Care Med* 1985; **13**: 818-829 [PMID: 3928249 DOI: 10.1097/00003246-198510000-00009]

18 **Sánchez Casado M**, Quintana Díaz M, Palacios D, Hortigüela V, Marco Schulke C, García J, Canabal A, Pérez Pedrero MJ, Velasco Ramos A, Arrese MA. Relationship between the alveolar-arterial oxygen gradient and PaO_2/FiO_2-introducing PEEP into the model. *Med Intensiva* 2012; **36**: 329-334 [PMID: 22154281 DOI: 10.1016/j.medin.2011.10.007]

19 **Ramsay MA**, Savege TM, Simpson BR, Goodwin R. Controlled sedation with alphaxalone-alphadolone. *Br Med J* 1974; **2**: 656-659 [PMID: 4835444 DOI: 10.1136/bmj.2.5920.656]

20 **Nassar BS**, Collett ND, Schmidt GA. The flow-time waveform predicts respiratory system resistance and compliance. *J Crit Care* 2012; **27**: 418.e7-418.14 [PMID: 22226421 DOI: 10.1016/j.jcrc.2011.10.012]

21 **Sociedade Brasileira de Pneumologia e Tisiologia**. Diretrizes brasileiras para tratamento das pneumonias adquiridas no hospital e das associadas à ventilação mecânica. *J Bras Pneumol* 2007; **33** Suppl 1: 1-30

22 **Zhang Z**. Univariate description and bivariate statistical inference: the first step delving into data. *Ann Transl Med* 2016; **4**: 91 [PMID: 27047950 DOI: 10.21037/atm.2016.02.11]

23 **Acuña K**, Costa E, Grover A, Camelo A, Santos Júnior R. Clinical-epidemiological characteristics of adults and aged interned in an intensive care unity of the Amazon (Rio Branco, Acre). *Rev Bras Ter Intensiva* 2007; **19**: 304-309 [PMID: 25310063 DOI: 10.1590/S0103-507X2007000300006]

24 **Rocha MS**, Caetano JÁ, Soares E, Medeiros FL. Caracterização da população atendida em unidade de terapia intensiva: subsídio para a assistência. *Rev enferm UERJ* 2007; **15**: 411-416

25 **Matic I**, Titlic M, Dikanovic M, Jurjevic M, Jukic I, Tonkic A. Effects of APACHE II score on mechanical ventilation; prediction and outcome. *Acta Anaesthesiol Belg* 2007; **58**: 177-183 [PMID: 18018838]

26 **Norena M**, Wong H, Thompson WD, Keenan SP, Dodek PM. Adjustment of intensive care unit outcomes for severity of illness and comorbidity scores. *J Crit Care* 2006; **21**: 142-150 [PMID: 16769457 DOI: 10.1016/j.jcrc.2005.11.011]

27 **Doak MW**, Nixon AC, Lupton DJ, Waring WS. Self-poisoning in older adults: patterns of drug ingestion and clinical outcomes. *Age Ageing* 2009; **38**: 407-411 [PMID: 19383772 DOI: 10.1093/ageing/afp046]

28 **Sudarsanam TD**, Jeyaseelan L, Thomas K, John G. Predictors of mortality in mechanically ventilated patients. *Postgrad Med J* 2005; **81**: 780-783 [PMID: 16344303 DOI: 10.1136/pgmj.2005.033076]

29 **Elliott D**. Measuring the health outcomes of general ICU patients: a systematic review of methods and findings. *Aust Crit Care* 1999; **12**: 132-140 [PMID: 11271027 DOI: 10.1016/S1036-7314(99)70598-9]

30 **Esteban A**, Anzueto A, Frutos F, Alía I, Brochard L, Stewart TE, Benito S, Epstein SK, Apezteguía C, Nightingale P, Arroliga AC, Tobin MJ; Mechanical Ventilation International Study Group. Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study. *JAMA* 2002; **287**: 345-355 [PMID: 11790214 DOI: 10.1001/jama.287.3.345]

31 **Azevedo LC**, Park M, Salluh JI, Rea-Neto A, Souza-Dantas VC, Varaschin P, Oliveira MC, Tierno PF, dal-Pizzol F, Silva UV, Knibel M, Nassar AP Jr, Alves RA, Ferreira JC, Teixeira C, Rezende V, Martinez A, Luciano PM, Schettino G, Soares M; ERICC (Epidemiology of Respiratory Insufficiency in Critical Care) investigators. Clinical outcomes of patients requiring ventilatory support in Brazilian intensive care units: a multicenter, prospective, cohort study. *Crit Care* 2013; **17**: R63 [PMID: 23557378 DOI: 10.1186/cc12594]

32 **Arabi Y**, Al-Shirawi N, Memish Z, Anzueto A. Ventilator-associated pneumonia in adults in developing countries: a systematic review. *Int J Infect Dis* 2008; **12**: 505-512 [PMID: 18502674 DOI: 10.1016/j.ijid.2008.02.010]

33 **Huang KT**, Tseng CC, Fang WF, Lin MC. An early predictor of the outcome of patients with ventilator-associated pneumonia. *Chang Gung Med J* 2010; **33**: 274-282 [PMID: 20584505]

34 **Mirsaeidi M**, Peyrani P, Ramirez JA; Improving Medicine through Pathway Assessment of Critical Therapy of Hospital-Acquired Pneumonia (IMPACT-HAP) Investigators. Predicting mortality in patients with ventilator-associated pneumonia: The APACHE II score versus the new IBMP-10 score. *Clin Infect Dis* 2009; **49**: 72-77 [PMID: 19480582 DOI: 10.1086/599349]

35 **Guimarães MMQ**, Rocco JR. Prevalência e prognóstico dos pacientes com pneumonia associada à ventilação mecânica em um hospital universitário. *Bras Pneumol* 2006; **32**: 339-346

36 **García-Leoni ME**, Moreno S, García-Garrote F, Cercenado E. Ventilator-associated pneumonia in long-term ventilator-assisted individuals. *Spinal Cord* 2010; **48**: 876-880 [PMID: 20404831 DOI: 10.1038/sc.2010.43]

37 **Tejerina E**, Frutos-Vivar F, Restrepo MI, Anzueto A, Abroug F, Palizas F, González M, D'Empaire G, Apezteguía C, Esteban A; Internacional Mechanical Ventilation Study Group. Incidence, risk factors, and outcome of ventilator-associated pneumonia. *J Crit Care* 2006; **21**: 56-65 [PMID: 16616625 DOI: 10.1016/j.jcrc.2005.08.005]

38 **Lorx A**, Suki B, Hercsuth M, Szabó B, Pénzes I, Boda K, Hantos Z. Airway and tissue mechanics in ventilated patients with pneumonia. *Respir Physiol Neurobiol* 2010; **171**: 101-109 [PMID: 20215004 DOI: 10.1016/j.resp.2010.03.004]

39 **Eastwood G**, Bellomo R, Bailey M, Taori G, Pilcher D, Young P, Beasley R. Arterial oxygen tension and mortality in mechanically ventilated patients. *Intensive Care Med* 2012; **38**: 91-98 [PMID: 22127482 DOI: 10.1007/s00134-011-2419-6]

40 **de Jonge E**, Peelen L, Keijzers PJ, Joore H, de Lange D, van der Voort PH, Bosman RJ, de Waal RA, Wesselink R, de Keizer NF. Association between administered oxygen, arterial partial oxygen pressure and mortality in mechanically ventilated intensive care unit patients. *Crit Care* 2008; **12**: R156 [PMID: 19077208 DOI: 10.1186/cc7150]

P- Reviewer: Jeong KJ, Zhang ZH **S- Editor**: Cui LJ **L- Editor**: A **E- Editor**: Li RF

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