Mechanical ventilation and acute kidney injury in patients in the intensive care unit

Ventilação mecânica e a lesão renal aguda em pacientes na unidade de terapia intensiva

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Keywords
Acute kidney injury; Respiration, artificial; Nursing assessment; Intensive care units

Descritores
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Abstract

Objective: To verify the impact of mechanical ventilation use in patients admitted to the intensive care unit and the incidence of acute kidney injury.
Methods: A prospective, quantitative cohort study of 27 patients receiving mechanical ventilatory support while hospitalized in the intensive care unit of a public hospital.
Results: The majority (55.6%) of patients were classified according to the kidney injury stages listed in the Risk, Injury, Failure, Loss, End-Stage (RIFLE) classification. Of these patients, 45.8% received mechanical ventilation with between 5 and 10 cmH2O positive end-expiratory pressure and progressed to acute kidney injury. The Acute Physiology and Chronic Health Disease Classification System II (APACHE II) was significantly associated with renal dysfunction ($p = 0.046$).
Conclusion: The use of invasive mechanical ventilator support with positive end-expiratory pressure in critically ill patients in intensive care units can impair renal function.

Resumo

Objetivo: Verificar o impacto do emprego da ventilação mecânica em pacientes internados na Unidade de Terapia Intensiva e a ocorrência de lesão renal aguda.
Métodos: Estudo de coorte, prospectivo, quantitativo, desenvolvido com 27 pacientes sob suporte de ventilação mecânica internados na unidade de terapia intensiva em um hospital público.
Resultados: A maioria (55,6%) dos pacientes foi classificada no estágio de lesão renal, de acordo com a classificação *Risk*, *Injury*, *Failure*, *Loss*, *End-Stage* (RIFLE). Dentre os pacientes, 45,8% estavam sob ventilação mecânica com pressão expiratória final positiva entre $5cmH_2O$ e $10cmH_2O$, os quais evoluíram com lesão renal aguda. *Acute Physiology and Chronic Health Disease Classification System* II (APACHE II) apresentou associação significativa com disfunção renal (p=0,046).
Conclusão: O emprego da ventilação mecânica invasiva com pressão expiratória final positiva em pacientes graves pode determinar prejuízos à função renal dos pacientes internados em unidade de terapia intensiva.

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Introduction

The development of acute kidney injury in hospitalized patients leads to longer hospitalization, with increased treatment costs and mortality rates. This reality reflects the urgent need to implement preventive measures to preserve renal function and minimize complications, along with strategies to decrease the need for renal replacement therapy.

Preventive measures should be initiated on the basis of the assessment of individuals at risk. These measures may be pharmacological or may involve actions to minimize exposure or susceptibility to the development of acute kidney injury.[1,2]

In the healthcare setting, mechanical ventilation has been a relevant factor in the development of acute kidney injury. The relationship between the lungs and kidneys has been firmly established as clinically important to the health–sickness processes, and several mechanisms have been proposed to explain this association.[3]

Currently, hemodynamic instability is considered one of the main determinants of acute kidney injury during mechanical ventilation.[4]

Studies in animal models have indicated that the use of positive end-expiratory pressure >10 cmH_2O results in a 40% decrease in urinary flow, 23% decrease in creatinine clearance, and 63% decrease in urinary sodium excretion. Studies on humans have also shown that increased positive end-expiratory pressure may cause a decrease in cardiac output, mean arterial pressure, sodium excretion, and glomerular filtration rate after 30 min of its use.[5]

From this perspective, mechanical ventilation combined with the high positive end-expiratory pressure causes significant changes in the cardiovascular hemodynamics, resulting in decreased renal blood flow. Any reduction in cardiac output affects renal blood flow and consequently the glomerular filtration rate, resulting in a possible prerenal state.[5,6]

There are three underlying mechanisms for acute kidney injury induced by mechanical ventilation: the effects of arterial blood gases, systemic release of inflammatory agents (biotrauma), and the influence on systemic and renal blood flow.[7]

Because acute kidney injury often affects individuals under the care of both nephrologists and other health professionals, awareness of this disease should be greater among all health professionals.[8]

Despite current scientific knowledge, the relationship between mechanical ventilation and the incidence of acute kidney injury remains unclear.[4] The objective of this study was to investigate the impact of mechanical ventilation in patients admitted to intensive care units and the incidence of acute kidney injury.

Methods

This was a prospective, quantitative cohort study conducted in the intensive care unit of a public hospital during the period August 2013 to February 2014.

The patient follow-up period was linked to the period they were exposed to mechanical ventilation.

The study included 27 patients aged >18 years who were exposed to mechanical ventilation with positive end-expiratory pressure and had no previous history of renal dysfunction. Patients with a history of chronic renal insufficiency (glomerular filtration rate <60 mL/min/1.73 m^2) or kidney transplantation were excluded, as were those hospitalized in the intensive care unit for ≤24 h.

Acute kidney injury was defined as an increase in serum creatinine levels to ≥50% from baseline levels or a decrease in urinary output to <0.5 ml/kg/h for more than 6 hours.[9]

The selected patients were allocated to groups according to the positive end-expiratory pressure programmed into the ventilator, as follows: Group 1, patients with positive end-expiratory pressure of ≤5 cmH_2O; Group 2, those with 5–10 cmH_2O; Group 3, those with ≥10 cmH_2O.

The results were expressed in absolute and relative frequency, median, and 25th and 75th percentiles. The analysis of categorical variables was performed using Fisher's exact test. Analysis of continuous variables was performed using the Mann–Whitney nonparametric test. P values of <0.05 were considered statistically significant.

This study adhered to the national and international ethical standards in research involving humans.

Results

Twenty-seven mechanically ventilated patients admitted to the intensive care unit were followed up. There was a predominance of males (59.3%) in the study population. The mean age was 50 years, the mean body mass index was 26 kg/m^2, and 40.7% of the subjects were overweight. The majority (66.7%) of the patients received a continuous infusion of vasoactive drugs, predominantly noradrenaline (53.3%). The mean APACHE II index score was 16 and the median mechanical ventilation time was 11 days. According to the RIFLE classification, all patients developed some stage of compromised renal function, and hypertension was the most frequent comorbidity (22.2%). During mechanical ventilation, most patients (70.4%) received between 5 and 10 cmH_2O positive end-expiry pressure. Of all the patients followed up, 44.4% died, as shown in table 1.

Table 1. Distribution of patients according to demographic and clinical characteristics

Characteristics (n=27)	n(%)	Mean (±SD)	Median (25th-75th %)
Age (years)	-	50±19	-
Male	16(59.3)	-	-
BMI (kg/m^2)*	-	26±9	-
Obese*	5(18.5)	-	-
Overweight*	11(40.7)	-	-
Use of vasoactive drugs	18(66.7)	-	-
Norepinephrine	16(53.3)	-	-
Dobutamine	1(3.7)	-	-
APACHE II**	-	16.2±4.5	-
Ventilation time (days)	-	-	11 (7-29)
Renal dysfunction (RIFLE)	27(100.0)	-	-
Comorbidities***			
Hypertension	6(22.2)	-	-
Diabetes	3(11.1)	-	-
Heart disease	1(3.7)	-	-
PEEP			
Group 1	1(3.7)	-	-
Group 2	19(70.4)	-	-
Group 3	7(25.9)	-	-
Deaths	12(44.4)	-	-

*4 patients with data; **18 patients with data; ***One or more sets of data per patient. SD: standard deviation; BMI: body mass index; APACHE: Acute Physiology and Chronic Health Disease Classification System II; RIFLE: Risk, Injury, Failure, Loss, End-Stage; PEEP: positive end-expiratory pressure; Group 1: PEEP ≤5 cmH2O; Group 2: PEEP between 5 and 10 cmH2O; Group 3: PEEP ≥10 cmH2O

The results showed that the majority (55.6%) of the patients were classified in the renal injury stage by the criteria serum creatinine and urinary flow of the RIFLE classification. However, according to the criterion urinary flow, 48.2% developed renal injury and 25.9% developed risk and renal failure. The criterion serum creatinine indicated 29.6% patients with renal injury and 14.8% with kidney failure.

Table 2 shows that 40.7% of patients on mechanical ventilation with positive end-expiratory pressure between 5 and 10 cmH_2O progressed to acute kidney injury and 25.9% to kidney failure. In Group 3 (positive end-expiratory pressure ≥10 cmH_2O), 11.1% were classified as having acute kidney injury, and the 11.1% were classified with renal failure. The use of positive end-expiratory pressure of <5 cmH_2O determined kidney injury in a lower percentage (3.7%) of patients.

Table 2. Distribution of patients by stages of renal dysfunction according to positive end-expiratory pressure

PEEP Group	RIFLE classification (n=27)		
	Risk n(%)	Kidney injury n(%)	Kidney failure n(%)
Group 1	0	1(3.7)	0
Group 2	1(3.7)	11(40.7)	7(25.9)
Group 3	1(3.7)	3(11.1)	3(11.1)

PEEP: positive end-expiratory pressure; RIFLE: Risk, Injury, Failure, Loss, End-Stage; Group 1: PEEP ≤5 cmH2O; Group 2: PEEP between 5 and 10 cmH2O; Group 3: PEEP ≥10 cmH2O

In this study, there was a statistically significant association between body mass index and death (p = 0.07), indicating that patients with body mass index ≥25 kg/m^2 were predisposed to increased mortality (p = 0.024). It was observed that patients with a body mass index ≥30 kg/m^2 required higher positive end-expiratory pressure (≥10 cmH_2O). The association between these variables was significant (p = 0.048).

Assessing the disease severity of the patients, it was possible to associate the APACHE II index of patients followed up in the study with the incidence of renal dysfunction; it was also found that patients admitted to the intensive care unit with a median APACHE II score of 18 were classified as being in the renal failure stage, and those with a median APACHE II score of 15 were classified as being at risk of kidney damage. This association was significant (p = 0.046).

Discussion

The limitations of this study were related to the lack of records in the electronic patient files and the small sample size. This may be because of the percentage of patients with renal dysfunction prior to admission to the intensive care unit (approximately 50%–60%). This study will hopefully contribute to promoting safe healthcare practices and clinical management of severely ill patients by nurses, through their professional qualification. The presence of competent professionals can help decrease patients' vulnerability to complications by increasing safety in the healthcare setting.[10]

Awareness of the real incidence of acute kidney injury and its lethal effects in various clinical settings has increased dramatically, leading to renewed interest in the diagnosis, prevention, and treatment of this pathology. The implementation of the RIFLE classification to identify and stage acute renal dysfunction has supported the early adoption of preventive measures in clinical practice in many healthcare institutions.[11,12]

Acute kidney injury is a recurring health problem in critically ill patients, and its incidence is increasing. It is estimated that 36% to 67% of patients in intensive care units develop renal dysfunction. In this study, this percentage was 100% according to the RIFLE classification. It is known that the causes are multifactorial and may be associated with various elements, such as hypovolemia, sepsis, nephrotoxins, and hemodynamic disturbances. Furthermore, scientific evidence suggests that mechanical ventilation is closely related to the development of renal dysfunction.[12,13]

The literature discusses increased positive end-expiratory pressure associated with mechanical ventilation as an important risk factor for the development of renal dysfunction. A meta-analysis showed that invasive mechanical ventilation is associated with a threefold increase in the likelihood of acute kidney injury in critically ill patients. Nevertheless, in general, positive end-expiratory pressure does not appear to significantly alter the risk of acute renal failure, as shown in this study.[4]

In this study, in patients on mechanical ventilation, the criterion urinary flow of the RIFLE classification had better discriminatory power to identify renal dysfunction compared with the criterion serum creatinine. It should be considered that the serum creatinine level lacks sensitivity and does not offer early, real-time assessment of the glomerular filtration rate, leading to the underestimation of the degree of renal dysfunction in critically ill patients.[4]

It is known that there are differences in the disease evolution in patients who spend <5 days in intensive care units compared with those who spend ≥5 days. Hospitalization duration of ≥5 days in intensive care units, combined with mechanical ventilation and emergency surgery, increase the risk of developing serious diseases. In this study, in particular, hospitalization duration in the intensive care unit were longer (approximately 11 days), which increased the risk of patients and predisposition to complications.[11]

The APACHE II score is a prognostic index used to assess the disease severity of patients admitted to intensive care units. Scientific evidence indicates that a score of >16 represents a risk factor for renal dysfunction, specifically for acute renal failure,[14] which was confirmed in this study.

Body mass index is the most commonly used marker of adiposity. In the general population, very low or high body mass indices are associated with increased mortality.[15,16] In severe cases, however, being underweight is an established prognostic factor for mortality, but the impact of being overweight or obese is still controversial.[17,18]

Studies with body mass index data collected 10 to 30 years ago have consistently found an increased risk of mortality among people who are severely obese (body mass index ≥35 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese people (30.0–34.9 kg/m^2).[19-21] In this study, a statistically significant relationship was seen between body mass index and mortality ($p = 0.024$). Patients with body mass index values of >25 cmH_2O presented a greater risk of death, and the need for higher levels of positive end-expiratory pressure. However, the results showed that the prevalence of acute kidney injury

increased significantly with increased body mass index. In addition, most of these patients were classified as being in the renal failure stage, with even higher percentage rates when body mass index was ≥25 kg/m^2. It was therefore demonstrated that the probability of developing acute renal failure in obese patients is twice that in individuals with a normal body mass index.[17]

In view of these findings, the work of a multidisciplinary team in intensive care units is essential to minimize and prevent the development of renal dysfunction, and to minimize its risk factors, given the complexity of the human body, especially when patients are hospitalized and in serious condition. In this aspect, it is essential to highlight that nurses represent the largest occupational group in the healthcare workforce, offering the utmost care, safety, and quality at all levels of care.[22]

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Collaboration

Santos LL participated in the design and execution of the project, collection and interpretation of data, and writing the article. Magro MCS contributed to the design, project planning, analysis and data interpretation stages, as well as to the writing and critical review of relevant intellectual content, and approved the final version for publication.

Conclusion

The use of invasive mechanical ventilation with positive end-expiratory pressure in critically ill patients can result in damage to kidney function in patients in intensive care units.

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