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M. Schneck · K. Holder · S. Gielen · S. Nuding · J. Schröder · A.R. Tamm · K. Werdan · H. Ebelt
Department of Medicine III, University Hospital of Halle, Martin-Luther University Halle-Wittenberg, Halle, Germany

Lung protective ventilation and hospital survival of cardiac intensive care patients

Introduction

Due to the paucity of clinical data, evidence-based recommendations for mechanical ventilation in cardiac intensive care patients are lacking. Therefore, it is a common practice to apply the guidelines that are established for patients suffering from acute respiratory distress syndrome (ARDS) [1] also to those patients with acute heart failure (AHF) and cardiogenic shock which are on mechanical ventilation [2].

In the ARDS guidelines, the parameters of lung protective ventilation (LPV) are well-established and is defined as ventilation mode with tidal volume (Vt) <6 ml/kg predicted body weight (pBW) and a peak inspiratory pressure (PIP) <30 mmHg [3].

This concept is mainly based on the ARDS-Network study, published in 2000, which had questioned the common practice of using higher Vts [1]. Before that study, Vts of 10–15 ml/kgBW were the standard of care because otherwise normal values of arterial carbon dioxide and pH value could often not be reached. The ARDS-Network study was the logical consequence of different experiments in animals which showed that high Vts are damaging the pulmonary endothelium and epithelium and increase the risk of hypoxemia, atelectasis, and increased release of inflammatory mediators [4]. It finally turned out that patients who were ventilated with low Vts showed a significant better survival [5]. Furthermore, the number of days without ventilation was increased and the inflammatory marker interleukin-6 was also found to be decreased within this group with LPV [4]. Additionally, Agnjen Gajic et al. [6] found an association between the use of high tidal volumina (>6 ml/kg pBW) and the increase of acute lung injury while mechanical ventilation. Unlike for ARDS, there are much less findings regarding the best ventilation strategy in the patients suffering from cardiac disease. However, the clinical outcomes in these patients that are in need of mechanical ventilation are very unsatisfactory [7].

Based on the paucity of available data, even the related guidelines can give only restrained advice about the optimal ventilation strategy in cardiac intensive care [2]. It is emphasized that noninvasive ventilation (NIV) can improve physiological parameters (e.g., oxygen saturation) in patients with acute lung edema. Nevertheless, so far it has not been conclusively shown that mortality or intubation rate in these patients is significantly decreased by NIV [8].

According to the ESC guidelines on heart failure [9], endotracheal intubation and mechanical ventilation are indicated in patients with AHF in the case of respiratory failure, hypercapnia, hypoxia, or acidosis [9].

Tab. 1 Baseline data

	Total *n* = 129	AHF *n* = 79	CPR *n* = 50
Age in years	67.9 ± 13.4	68.3 ± 11.9	67.3 ± 15.7
Gender male [%]	88 (68.2 %)	57 (72.2 %)	31 (62.0 %)
Height (m)	1.72 ± 0.08	1.72 ± 0.08	1.72 ± 0.07
Weight (kg)	71.4 ± 37.2	75.6 ± 36.5	64.7 ± 37.7
Predictives body weight (kg)	56.0 ± 26.1	58.5 ± 24.0	52.1 ± 28.8
BMI kg/m^2	23.9 ± 12.6	25.4 ± 11.8	21.5 ± 13.5
APACHE II score	26.7 ± 9.8	25. 5 ± 8.6	28.7 ± 11.3
Medical history			
Hypertension *n* (%)	77 (59.7 %)	49 (62.0 %)	28 (56.0 %)
Diabetes *n* (%)	54 (41.9 %)	41 (51.9 %)	13 (26.0 %)
Renal insufficiency *n* (%)	39 (30.2 %)	25 (31.6 %)	14 (28.0 %)
Chronic hemodialysis *n* (%)	7 (5.4 %)	5 (6.3 %)	2 (4.0 %)
Coronary heart disease *n* (%)	70 (54.3 %)	47 (59.5 %)	23 (46.0 %)
Heart failure *n* (%)	16 (12.4 %)	10 (12.7 %)	6 (12.0 %)
COPD *n* (%)	13 (10.1 %)	8 (10.1 %)	5 (10.0 %)
Outcome parameter			
Tracheostomy	12 (9.3 %)	10 (12.7 %)	2 (4.0 %)
In-hospital mortality	61 (47.3 %)	27 (34.3 %)	34 (68.0 %)
Mean hospital stay of the survived [d]	16.1 ± 16.4	16.5 ± 17.9	14.7 ± 10.0
Renal replacement therapy	33 (25.6 %)	21 (26.6 %)	12 (24.0 %)

K. Holder and M. Schneck contributed equally to this work.

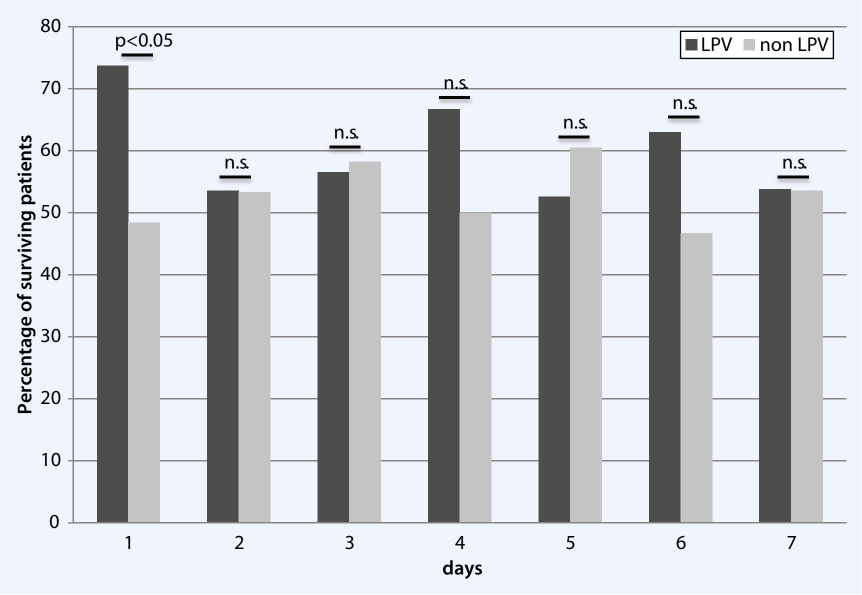

Fig. 1 ▲ Percentage of survived patients in respect to lung protective ventilation during the first 7 days of mechanical ventilation

The aim of our study was to describe how patients with severe AHF or after cardiopulmonary resuscitation (CPR) are ventilated in everyday clinical practice and to identify correlations between ventilator settings and clinical outcomes in these patients.

Methods

During a period of 12 months (01-MAY-2011 until 30-APR-2012), all mechanically ventilated patients at the medical intensive care unit (ICU; 13 beds) of the University Hospital of Halle (Saale), Germany, were included in the study if ICU admission was primarily due to cardiac disease. All patients were observed in a prospective way. Overall, 129 patients were included in the study. Among these, there were 79 patients with AHF and 50 patients after successful CPR. The 79 patients with AHF consisted of 23 (29 %) patients with cardiogenic shock, 27 (34 %) patients with lung edema, 14 (18 %) patients with ST-segment elevation myocardial infarction, and 15 (19 %) patients with non-ST elevation myocardial infarction.

After admission to the ICU, the following parameters were recorded: medical history, height, body weight, pBW, body mass index (BMI), and APACHE II-score. Furthermore, the following parameters of ventilation were documented immediately after ICU-admission and thereafter on a daily basis at 06:00 am: mode of ventilation, PIP, positive end-expiratory pressure (PEEP), respiratory rate, fraction of inspired oxygen (FiO_2), Vt, minute volume, Horowitz-Index (HI, calculated as follows: $HI = paO_2/FiO_2$), arterio-alveolar oxygen-pressure difference ($AaDO_2$, calculated as follows: $103{,}8 * FiO_2 - paCO_2 - paO_2$) and driving pressure (driving pressure = PIP –PEEP). Additionally, parameters of blood gas analysis and the following outcome parameters were prospectively recorded: need for tracheotomy, need of renal replacement therapy, in-hospital mortality, length of hospital stay.

In accordance with the ARDS network guidelines [1], a patient who was in a pressure-controlled mode of ventilation (BIPAP or PC) was considered to be treated with "LPV" if the following ventilator settings were chosen: PIP < 30 mmHg and Vt <= 6 ml/kg pBW (calculated for men: 50 + 0,91 [body size (cm)—152,4] and women: 45,5 + 0,91 [body size (cm)—152,4] [2]). All clinical parameters were collected every day at 6:00 am for the first 7 days under mechanical ventilation. The primary endpoint of the study was hospital mortality.

At the ICU, the following ventilators were used: Evita Infinity® V500 (Draeger), Evita Infinity® C500 (Draeger), Evita XL® (Drager), Servo Ventilator® 300A (Siemens).

The analysis of the data was performed with SPSS Statistics 20.0 (SPSS Inc. Chicago, IL, USA). All data were recorded in an anonymous way. The study was performed according to the regulations of the ethics committee of the Martin Luther University Halle-Wittenberg.

Results

During the period of observation, 129 patients with cardiovascular disease requiring mechanical ventilation were included into the study. The demographic data, the medical history, and the outcome parameters are shown in ■ **Tab. 1**. As expected, mortality was significantly higher in patients after CPR in comparison to patients with AHF.

Ventilator settings and the derived parameters during the course of ventilation are given in ■ **Tab. 2**. As seen in the table, the percentage of patients with augmented spontaneous breathing was only 20 % on day 1 but subsequently rose up to 80 % on day 7. In parallel, mean PIP showed a clear decrease from day 1 to day three and remained stable thereafter. Vt was kept at a relatively constant level over the analyzed period of time.

Within the 129 patients, only 17.3 % received LPV on day 1 (AHF: 13 pat. = 18.8 %; CPR: 6 pat. = 14.6 %). However, the early establishment of LPV was associated with an improved survival as seen from ■ **Fig. 1**.

■ **Tab. 3** shows in more detail which percentage of patients reached the two different ventilation goals (PIP; Vt) that together determine LPV. Obviously, the cutoff for PIP was maintained in a high percentage of patients throughout the whole observational period whereas the Vt exceeded 6 ml/kgBW in the vast majority of patients throughout the study.

For more precise information about the impact of PIP or Vt on hospital mortality, two binary logistic regression models were established (■ **Tab. 4**). All patients receiving pressure controlled respiratory modes (PC, BIPAP) were included in this model. First, the individual parameters were analyzed in a univariante way. Additionally, the analysis was repeat-

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Abstract

Objective. To detect connections between parameters of ventilation and outcomes of cardiac intensive care patients.

Design and setting. Noninterventional study. Between 05/11 and 05/12 all patients with acute heart failure and post cardiopulmonary resuscitation were registered. Lung protective ventilation was defined as peak inspiratory pressure (PIP) < 30 mmHg and tidal volume (Vt) $<= 6$ ml/kg.

Results. In total, 129 patients were included in the study, 68.2 % male, age 67.9 ± 13.4 years, weight 71.4 ± 37.2 kg, predictive body weight 66.9 ± 8.8 kg, mortality 47.3 %. Lung protective ventilated patients at day 1: 17.3 % with a significant difference between surviving and nonsurviving patients (24.1 % vs. 9.6 %; $p < 0.05$). Logistic regression models showed a strong connection between PIP and survival (odds ratio 1.13; $p < 0.05$). Vt showed no significant influence on survival.

Conclusion. Our data recommends a strict observance of a low PIP for cardiac intensive care patients, whereas Vt seems to be of secondary importance.

Keywords

Lung protective ventilation · Acute heart failure · Cardiopulmonary resuscitation · Tidal volume · Peak inspiratory pressure · Lung protection

Lungenprotektive Beatmung und Krankenhaussterblichkeit bei kardiologischen Intensivpatienten

Zusammenfassung

Zielstellung. In dieser Studie sollen Zusammenhänge zwischen Beatmungsparametern und der Krankenhaussterblichkeit kardiologischer Intensivpatienten untersucht werden. Bislang gibt es nur wenige Empfehlungen zur Beatmung kardiologischer Intensivpatienten. Häufig wird auf Leitlinien zurückgegriffen, die für Patienten mit Acute Respiratory Distress Syndrome (ARDS) etabliert wurden. Diese Praxis soll überprüft werden.

Methoden. Alle beatmeten Patienten der internistischen Intensivstation (ITS) des Universitätsklinikum Halle (Saale) mit akuter Herzinsuffizienz (AHF) oder nach kardiopulmonaler Reanimation (CPR) zwischen 05/2011-05/2012 sind in die Beobachtungsstudie eingeschlossen. Als „lungenprotektiv beatmet" gelten Patienten, die bei kontrolliertem Beatmungsmodus folgende Grenzwerte einhalten: PIP < 30 mmHg und Vt ≤ 6 ml/kg. Logistische Regressionen werden genutzt, um Korrelationen zwischen Beatmungsparametern und der Krankenhaussterblichkeit zu identifizieren.

Ergebnisse. Erfasst sind 129 Patienten, (68 % männlich; Alter 67,9 ± 13,4 Jahre; Körpergewicht (KG) 71,4 ± 37,2 kg, prädiktives KG 66,9 ± 8,8 kg, Krankenhaussterblichkeit 47,3 %). Lungenprotektiv beatmet sind an Tag 1 17,3 % der Patienten. 73,7 % der lungenprotektiv beatmeten und nur 48,4 % der nicht-lungenprotektiv beatmeten Patienten überleben ($p < 0{,}05$). Einen relevanten Zusammenhang mit der Mortalität zeigen außerdem die Parameter Beatmungsdruck (PIP) mit einer Odds Ratio (OR) von 1,15 ($p = 0{,}001$), FiO_2 (OR: 1,03; $p < 0{,}001$), Horowitz-Index (OR: 0,97; $p = 0{,}015$), $AaDO_2$ (OR: 1,03; $p < 0{,}001$) und driving pressure (OR: 1,11; $p = 0{,}006$).

Schlussfolgerung. Eine lungenprotektive Beatmung ist in dieser Studie mit einem Überlebensvorteil für die untersuchten kardiologischen Intensivpatienten assoziiert. Insbesondere die Einhaltung eines niedrigen PIP ist in dieser Studie prognostisch günstig, wohingegen der Einfluss des körpergewichtsbezogenen Tidalvolumens von untergeordneter Bedeutung erscheint.

Schlüsselwörter

Lungenprotektive Beatmung · Akute Herzinsuffizienz · Kardiopulmonale Reanimation · Tidalvolumen · Inspiratorsicher Spitzendruck

ed in a multivariate manner were the potential confounders age, BMI, APACHE II score on admission and application of catecholamines were taken into consideration. The parameters age and body mass index were chosen linked to their influence in prior morbidity. As markers for the severity of disease, APACHE II score and the use of catecholamines were selected. APACHE II score lines out the severity of disease after admission on the ICU and the use of catecholamines the severity of cardiogenic shock.

It turns out that both in the univariante as well as in the multivariate model PIP is closely linked to mortality whereas, however, such a correlation cannot be found for Vt.

Discussion

Both patients with AHF and patients post CPR are mostly critically ill and have poor outcomes—especially if they are in need of mechanical ventilation. There are different theories why respiratory failure and the use of mechanical ventilation increase the mortality of patients with AHF. One of the reasons could be that these patients often already suffer from cardiogenic shock and subsequent systemic hypoperfusion [10]. Another explanation is that the ventilation-induced increase in intrathoracic pressure has a complex influence on left and right heart function. For an instance, it has been shown that small changes in the intrathoracic pressure can result in large changes in stroke volume [10].

The outcomes in patients after CPR remain poor, even though many efforts have been made to increase the survival of these patients. In an analysis of 12,000 patients treated by emergency medical services (EMS) in Seattle, the percentage of patients that were discharged alive from hospital after cardiac arrest did not differ significantly between 1998–2001 and 1977–1981 (15.7 vs. 17.5 %) [11]. This study also tried to find reasons for the overall poor survival of these patients but was not

Tab. 2 Parameter of ventilation during the first 7 days of mechanical ventilation

	d1 *n* = 129	d2 *n* = 99	d3 *n* = 88	d4 *n* = 81	d5 *n* = 66	d6 *n* = 52	d7 *n* = 43
Ventilation mode							
BIPAP	54 (45.0 %)	39 (39.4 %)	23 (26.1 %)	17 (21.0 %)	9 (13.6 %)	6 (11.5 %)	4 (9.3 %)
NIV	3 (2.5 %)	2 (2.0 %)	1 (1.1 %)	1 (1.2 %)	0 (0.0 %)	0 (0.0 %)	0 (0.0 %)
PC	42 (35.0 %)	36 (36.4 %)	25 (28.4 %)	16 (19.8 %)	12 (18.2 %)	7 (13.5 %)	4 (9.3 %)
PS	21 (17.5 %)	22 (22.2 %)	39 (44.3 %)	47 (58.0 %)	45(68.2 %)	39 (75.0 %)	35 (81.4 %)
PIP [mmHg]							
Total	25.1 ± 6.6	22.9 ± 5.2	21.9 ± 5.2	21.4 ± 5.3	21.3 ± 5.1	20.3 ± 5.2	20.2 ± 5.5
AHF	23.8 ± 5.4	22.6 ± 5.1	21.6 ± 5.0	20.9 ± 4.8	21.4 ± 5.0	20.6 ± 5.3	20.6 ± 5.9
CPR	27.3 ± 7.6	23.3 ± 5.5	22.5 ± 5.5	22.5 ± 6.2	21.1 ± 5.4	19.9 ± 5.1	19.5 ± 5.0
PEEP [mmHg]							
Total	9.4 ± 2.9	9.5 ± 2.6	9.2 ± 2.7	9.0 ± 2.8	8.5 ± 2.7	8.1 ± 2.8	8.3 ± 2.9
AHF	9.4 ± 3.2	9.4 ± 2.6	9.2 ± 2.9	8.8 ± 2.8	8.6 ± 2.5	8.1 ± 3.1	8.9 ± 3.1
CPR	9.5 ± 2.5	9.8 ± 2.5	9.1 ± 2.4	9.2 ± 2.8	8.4 ± 3.2	8.1 ± 2.3	7.1 ± 2.0
Respiratory rate [/min]							
Total	21.4 ± 5.3	22.5 ± 4.5	21.8 ± 6.3	23.0 ± 6.7	24.2 ± 6.1	22.6 ± 7.2	22.4 ± 7.7
AHF	21.3 ± 5.6	21.9 ± 4.7	22.3 ± 6.2	23.6 ± 6.6	23.7 ± 5.7	23.1 ± 6.6	23.6 ± 8.1
CPR	21.6 ± 4.7	23.4 ± 3.9	21.0 ± 6.4	22.0 ± 7.0	25.2 ± 6.9	21.9 ± 8.5	20.3 ± 6.5
FiO$_2$ [%]							
Total	67.3 ± 26.0	45.7 ± 20.4	44.0 ± 19.4	44.6 ± 18.5	43.0 ± 18.2	39.8 ± 15.5	45.0 ± 19.9
AHF	65.3 ± 25.9	45.3 ± 19.4	45.4 ± 20.3	44.1 ± 18.9	42.2 ± 18.3	40.7 ± 17.5	46.5 ± 22.0
CPR	70.5 ± 26.3	46.4 ± 22.2	41.5 ± 17.7	45.6 ± 18.0	44.6 ± 18.4	38.2 ± 11.3	42.1 ± 15.3
Vt (predictive BW) [ml/kgKG]							
Total	7.5 ± 2.4	6.8 ± 1.9	6.9 ± 2.2	6.9 ± 2.0	6.6 ± 2.2	7.1 ± 3.0	7.1 ± 2.2
AHF	7.6 ± 2.1	7.0 ± 2.0	6.7 ± 2.2	6.9 ± 1.9	6.9 ± 1.7	6.9 ± 1.7	6.9 ± 2.0
CPR	7.2 ± 3.0	6.2 ± 1.6	7.3 ± 2.1	7.0 ± 2.4	6.1 ± 2.8	7.4 ± 4.5	7.4 ± 2.7
Minute volume [l/min]							
Total	10.2 ± 3.3	9.6 ± 2.7	9.8 ± 3.0	10.0 ± 3.0	10.9 ± 2.6	10.4 ± 3.0	9.8 ± 3.1
AHF	10.3 ± 3.4	9.8 ± 3.0	9.9 ± 3.0	10.2 ± 3.0	11.2 ± 2.6	10.5 ± 3.0	9.8 ± 3.1
CPR	10.0 ± 3.3	9.4 ± 2.2	9.5 ± 3.1	9.7 ± 3.0	10.5 ± 2.5	10.2 ± 3.3	9.6 ± 3.1
Horowitz-Index (pAO$_2$/FIO$_2$) [mmHg]							
Total	251.3 ± 151.6	260.9 ± 118.9	252.9 ± 108.6	245.4 ± 94.5	257.7 ± 97.1	271.7 ± 95.7	245.1 ± 94.5
AHF	252.8 ± 153.3	268.0 ± 122.4	254.6 ± 113.3	247.7 ± 96.7	264.3 ± 102.7	276.5 ± 101.4	247.6 ± 105.4
CPR	249.0 ± 150.3	249.1 ± 113.5	250.0 ± 101.7	240.6 ± 91.1	245.3 ± 86.7	262.7 ± 85.9	240.1 ± 72.0
AaDO$_2$ [mmHg]							
Total	36.7 ± 24.7	23.3 ± 19.5	23.0 ± 18.0	23.5 ± 17.7	22.1 ± 17.0	18.5 ± 14.8	23.3 ± 18.3
AHF	35.7 ± 24.9	22.5 ± 18.5	24.2 ± 18.9	23.2 ± 18.2	21.9 ± 17.9	19.2 ± 16.7	24.5 ± 20.7
CPR	38.3 ± 24.5	24.8 ± 21.1	21.0 ± 16.5	24.2 ± 16.7	21.9 ± 15.7	17.2 ± 10.6	20.8 ± 13.0
Driving pressure (PIP-PEEP) [mmHg]							
Total	15.7 ± 7.7	13.4 ± 7.3	12.7 ± 7.3	12.4 ± 7.4	12.8 ± 8.1	12.2 ± 8.4	11.9 ± 7.5
AHF	14.4 ± 7.0	13.2 ± 7.5	12.4 ± 7.0	12.1 ± 7.2	12.8 ± 9.1	12.5 ± 8.5	11.7 ± 6.9
CPR	17.8 ± 8.8	13.5 ± 7.7	13.4 ± 8.2	13.3 ± 8.4	12.7 ± 6.4	11.8 ± 9.3	12.4 ± 8.9

AHF acute heart failure, *CPR* cardio pulmonary resuscitation.

able to determine specific causes which could be potentially influenced by therapeutic strategies [11]. These results underline the need for further attempts to improve the survival of critically ill patients with cardiac disease.

While there are a number of profound studies regarding mechanical ventilation in ARDS patients, nearly no high-quality evidence exists on mechanical ventilation in cardiac intensive care patients. Therefore, the optimal ventilation strategy for AHF patients is unknown and the recommendations regarding mechanical ventilation in AHF-patients are mainly based on the ARDS-studies [2], as the guideline Cardiogenic Shock Due to Myocardial Infarction recommends [2].

As something like a first step on the way to evidence-based ventilation strategies in cardiac intensive care patients, our study presented here tried to describe how patients suffering from AHF or survived sudden cardiac death are ventilated in everyday clinical practice.

In our study, 89 % of the patients were ventilated with a PIP of less than 30 mmHg

Tab. 3 Parameters of lung protective ventilation during of the first 7 days of mechanical ventilation

Total ($n=129$)	d1 $n=129$	d2 $n=99$	d3 $n=88$	d4 $n=81$	d5 $n=66$	d6 $n=52$	d7 $n=43$
PIP < 30 mmHG	114 (88.4 %)	93 (93.9 %)	85 (96.5 %)	75 (92.6 %)	65 (98.5 %)	51 (98.1 %)	43 (100.0 %)
Tidal volume (predictive BW) < 6 ml/kgBW	24 (18.6 %)	24 (24.2 %)	24 (27.3 %)	21 (25.2 %)	19 (28.8 %)	17 (32.7 %)	13 (30.2 %)
Lung protective ventilation	19 (14.7 %)	19 (19.2 %)	23 (26.1 %)	18 (22.2 %)	19 (28.8 %)	16 (30.8 %)	13 (30.2 %)
AHF ($n=79$)	d1 $n=79$	d2 $n=63$	d3 $n=57$	d4 $n=53$	d5 $n=43$	d6 $n=33$	d7 $n=28$
PIP < 30 mmHG	72 (91.1 %)	59 (93.7 %)	55 (96.5 %)	50 (94.3 %)	42 (97.7 %)	33 (100.0 %)	28 (100.0 %)
Tidal volume (predictive BW) < 6 ml/kgBW	14 (17.7 %)	14 (22.2 %)	16 (28.1 %)	13 (24.5 %)	9 (20.9 %)	8 (24.2 %)	10 (35.7 %)
Lung protective ventilation	13 (16.5 %)	12 (19.0 %)	15 (26.3 %)	12 (22.6 %)	9 (20.9 %)	8 (24.2 %)	10 (35.7 %)
CPR ($n=50$)	d1 $n=50$	d2 $n=36$	d3 $n=31$	d4 $n=28$	d5 $n=23$	d6 $n=19$	d7 $n=15$
PIP < 30 mmHG	42 (84.0 %)	34 (94.4 %)	30 (96.8 %)	25 (89.3 %)	23 (100.0 %)	18 (94.7 %)	15 (100.0 %)
Tidal volume (predictive BW) < 6 ml/kgBW	10 (20.0 %)	10 (27.8 %)	8 (25.8 %)	8 (28.6 %)	10 (43.5 %)	9 (47.4 %)	3 (20.0 %)
Lung protective ventilation	6 (12.0 %)	7 (19.4 %)	8 (25.8 %)	6 (21.4 %)	10 (43.5 %)	8 (42.1 %)	3 (20.0 %)

Tab. 4 Influence of different parameters on hospital mortality in cardiac intensive care patients under controlled mechanical ventilation

	Univariate logistic regression model						*Multivariate logistic regression model*					
	Total ($n=96$)		**AHF ($n=54$)**		**CPR ($n=43$)**		**Total ($n=96$)**		**AHF ($n=54$)**		**CPR ($n=43$)**	
	OR	***p*-value**	**OR**	***p*-value**	**OR**	***p*-value**	**OR**	***p*-value**	**OR**	***p*-value**	**OR**	***p*-value**
Minute volume	0.92	n.s.	0.86	n.s.	0.98	n.s.	0.90	n.s.	0.80	n.s.	1.00	n.s.
PIP	1.13	0.009	1.07	n.s.	1.17	n.s.	1.13	0.002	1.02	n.s.	1.16	n.s.
PEEP	1.15	n.s.	0.81	n.s.	1.06	n.s.	1.14	n.s.	1.26	n.s.	1.05	n.s.
Vt (predictive BW)	0.94	n.s.	0.87	n.s.	1.01	n.s.	1.05	n.s.	0.99	n.s.	1.19	n.s.
Respiratory rate	1.02	n.s.	1.11	n.s.	0.95	n.s.	0.98	n.s.	1.02	n.s.	0.95	n.s.
FIO_2	17.36	0.001	1.03	0.027	1.04	0.017	1.03	0.003	1.03	n.s.	1.04	0.026
Horowitz-Index	0.98	0.020	0.98	n.s.	0.96	0.042	0.97	0.032	0.99	n.s.	0.96	0.047
$AaDO_2$	1.03	0.001	1.03	0.024	1.05	0.013	1.03	0.002	1.02	n.s.	1.05	0.015
Driving pressure	1.08	n.s.	1.00	n.s.	1.14	n.s.	1.08	0.047	0.94	n.s.	1.12	n.s.
							Adjusted for: Age, BMI, APACHEII Score, Application of catecholamines					

on the first day after initiation of ventilation with a further increase of this number within the next days. However, only 22.4 % of these patients received ventilation using low Vts with Vt < 6 ml/kgBW. Accordingly, the percentage of patients receiving "LPV" defined as the combination of both low Vt and PIP was even lower (17.3 %).

Although these numbers are certainly far away from our treatment goals, they are in line with previous reports showing that in everyday practice the adherence to ventilation guidelines is still limited. An analysis from 2004 of 10 ICUs in Europe showed that only 8 % of the included patients were ventilated using Vt < 6 ml/kgKG [12]. This is of note because already in 2000 it had been conclusively shown that the application of low Vts is indeed beneficial for patients with ARDS: the ARDS-network found a mortality rate of 39.8 % in the patients treated with traditional Vts that was significantly reduced to 31.0 % in patients ventilated with lower Vts. Similar to the study of Brun-Buisson et al. [12] the reason for the low percentage of lung protected ventilated patients in this study remain unclear.

These finding can also be seen in our study with cardiac intensive care patients: these patients show a better survival if the LPV was applied early. In our analysis, 73.7 % of the patients treated with LPV survived, whereas only 48.4 % patients of the patients ventilated in a non-lung-protective could be discharged alive. This result indicates that the early use of LPV as established for ARDS is also reasonable in patients with AHF and post CPR.

In our study, different parameters of ventilation were linked to the prognosis of cardiac intensive care patients, whereas other parameters seemed to be of less importance. As expected, both FiO_2, HI as well as $AaDO_2$ which all can be considered as markers of the severity of gas exchange disturbance were significantly linked to mortality (both univariate and multivariate logistic regression model).

Most of these parameters are also known to be of prognostic importance in ARDS patients from earlier studies [13].

These parameters mentioned above reflect the disturbance of the pulmonary gas exchange. However, our logistic regression analyses also revealed that there are ventilator settings which are directly tuned by the treating physicians that seem to have a significant influence on mortality in cardiac intensive care patients. Unexpectedly, our analysis suggests that in cardiac intensive care patients the limitation of PIP seems to be of much more importance than the adherence to a Vt of 6 ml/kg. This is contrary to the results of the studies in ARDS-patients that suggest both parameters to be important for the clinical outcome [3].

The ALKK registry had previously shown that the main ventilation mode in patients suffering from acute myocardial infarction was BIPAP and CPPV (continous positive pressure ventilation). There was a significant increase in mortality in patients with CPPV-use [7]. This connection could not be shown in our study because only patients with pressure controlled modes were included in the regression analysis.

It is noteworthy that in our study, the influence of the different parameters of mechanical ventilation on clinical outcomes was found for the whole cohort of cardiac intensive care patients whereas statistical significance got lost in the two subgroups of patients suffering from acute heart failure and after cardiopulmonal resuscitation. This might be explained by the limited number of AHF and CPR patients within the study. Furthermore, the low percentage of lung protective ventilated patients in this study could influence the results. Future studies with larger numbers of patients will have to deepen the influence on these two groups.

Conclusion

In summary, the results of the study presented here suggest that a lung protective way of ventilation with a limitation of both PIP as well as Vt as it has become standard of care for patients suffering from ARDS might also be advantageous for cardiac ICU patients. Especially the strict reduction of PIP seems to be of prognostic importance and might be even more relevant than the limitation of Vt.

Corresponding address

M. Schneck
Department of Medicine III,
University Hospital of Halle,
Martin-Luther University Halle-Wittenberg
Ernst-Grube-Str. 40, 06097 Halle
Michael.Schneck@uk-halle.de

Compliance with Ethics Guidelines

Conflict of interest. M. Schneck, K. Holder, S. Gielen, S. Nuding, J. Schröder, A.R. Tamm, K. Werdan and H. Ebelt state that there are no conflicts of interest.

All procedures followed were in accordance with the ethical standards of the ethics committee of the Martin Luther University Halle-Wittenberg.

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