Journal of Critical Care 30 (2015) 1232–1237

Contents lists available at ScienceDirect

Journal of Critical Care

journal homepage: www.jccjournal.org

Atelectasis and mechanical ventilation mode during conservative oxygen therapy: A before-and-after study

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ARTICLE INFO

Keywords:
Oxygen inhalation therapy
Hyperoxia
Mechanical ventilation
Atelectasis
Critical illness
Oxygen

ABSTRACT

Purpose: The purpose of the study is to assess the effect of a conservative oxygen therapy (COT) (target SpO_2 of 90%-92%) on radiological atelectasis and mechanical ventilation modes.
Materials and methods: We conducted a secondary analysis of 105 intensive care unit patients from a pilot before-and-after study. The primary outcomes of this study were changes in atelectasis score (AS) of 555 chest radiographs assessed by radiologists blinded to treatment allocation and time to weaning from mandatory ventilation and first spontaneous ventilation trial (SVT).
Results: There was a significant difference in overall AS between groups, and COT was associated with lower time-weighted average AS. In addition, in COT patients, change from mandatory to spontaneous ventilation or time to first SVT was shortened. After adjustment for baseline characteristics and interactions between oxygen therapy, radiological atelectasis, and mechanical ventilation management, patients in the COT group had significantly lower "best" AS (adjusted odds ratio, 0.28 [95% confidence interval {CI}, 0.12-0.66]; $P = .003$) and greater improvement in AS in the first 7 days (adjusted odds ratio, 0.42 [95% CI, 0.17-0.99]; $P = .049$). Moreover, COT was associated with significantly earlier successful weaning from a mandatory ventilation mode (adjusted hazard ratio, 2.96 [95% CI, 1.73-5.04]; $P < .001$) and with shorter time to first SVT (adjusted hazard ratio, 1.77 [95% CI, 1.13-2.78]; $P = .013$).
Conclusions: In mechanically ventilated intensive care unit patients, COT might be associated with decreased radiological evidence of atelectasis, earlier weaning from mandatory ventilation modes, and earlier first trial of spontaneous ventilation.

1. Introduction

Supplemental oxygen is a universal therapy in mechanically ventilated patients and can be lifesaving [1]. However, supplemental oxygen therapy may also cause adverse physiological effects and deleterious clinical outcomes [1-6]. Such reports suggest that oxygen therapy can be a 2-edged sword and that attempts should be made to optimize its use and avoid both inadequate and excessive oxygen administrations. Despite these concerns, current oxygen therapy in mechanically ventilated patients remains biased toward liberal administration. Thus, much excess oxygen is delivered without evidence of benefit and sometimes outside of published guidelines [7-10].

Recently, we reported the first pilot before-and-after trial of oxygen therapy in mechanically ventilated patients targeting a SpO_2 of 90% to 92% (conservative oxygen therapy [COT]). We found that such therapy could be safely implemented in the intensive care unit (ICU) [11]. Concerns, however, were raised on the impact of COT on mechanical ventilation (MV) management and the development of pulmonary atelectasis [12] because no information was provided on such outcomes in the primary analysis of the study.

To respond to such concerns, we conducted a secondary analysis of our before-and-after trial and focused on the relationship between COT, MV management, and radiological evidence of atelectasis.

2. Methods

The study design was previously described [11] and is reported in the electronic supplement. It was approved by the institutional human research ethics committee with waiver for informed consent (approval no. H2011/04252) and registered at ClinicalTrial.gov (NCT01684124). In brief, we studied patients older than 18 years and expected to require MV for more than 48 hours. Exclusion criteria were imminent death or extracorporeal membrane oxygenation. During the standard oxygen therapy period, oxygenation goals were prescribed by bedside clinicians

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http://dx.doi.org/10.1016/j.jcrc.2015.07.033
0883-9441/

unaware of a planned practice change. After a phase-out period of education and preparation, COT commenced with screening of all consecutive admissions. If a patient was eligible, a SpO_2 target between 90% and 92% was prescribed to be achieved using the lowest possible fraction of inspired oxygen (FiO_2).

The mode of MV was set by the attending clinicians according to clinical judgment and could include all modalities (no defined protocol). The typical target tidal volume in our ICU during the study was between 6 and 8 mL/kg, which was standard practice in the ICU and was not changed during the study period.

2.1. Radiographic evaluation of atelectasis

All chest x-rays (CXRs) during the study period were graded by 3 radiologists blinded to all clinical information and treatment according to a published atelectasis score (AS) [13] (Fig. 1). If 2 or more radiologists gave the same score to a CXR, the score was adopted. If there was a discrepancy between all 3 radiologists, the median score was chosen. The worst score was applied when more than 1 CXR was performed on a given day. Fleiss' κ statistic was used to assess interrater agreement in AS. Moderate agreement was defined if the κ value was between 0.41 and 0.60; substantial agreement, if it was between 0.61 and 0.80; and almost perfect agreement, if it was greater than 0.80 [14]. The "best" AS was defined as the lowest AS, and the "worst" was defined as the highest AS (except at baseline). We calculated the difference between baseline AS and best AS (ΔAS_{best}) and worst AS (ΔAS_{worst}). To minimize surveillance bias, we also calculated the time-weighted averages for AS.

2.2. Mechanical ventilation mode

We collected MV data and oxygenation data 6 hourly and followed up patients until free of MV for more than 24 consecutive hours or until death (whichever occurred first). Continuous mandatory ventilation and synchronized intermittent mandatory ventilation were regarded as mandatory modes. Pressure support ventilation and spontaneous breathing through a tracheostomy or endotracheal tube with a T-piece circuit were regarded as spontaneous ventilation.

2.3. Statistical analysis

Continuous data are reported as means (SD) or medians (interquartile range). Comparisons were made using the Student t test or Wilcoxon rank sum test when appropriate. Categorical data are reported as proportions and compared with Fisher exact test.

The primary outcomes of this study were changes in AS and time to weaning from mandatory ventilation and first spontaneous ventilation trial (SVT). Percentage of time spent on mandatory ventilation and AS-related variables were compared between groups. Analysis of time to first SVT and weaning from mandatory ventilation was also performed by means of the log-rank test, with Kaplan-Meier cumulative incidence plot. Time to weaning from mandatory ventilation was defined as the time until the patient was free of mandatory support for greater than 24 consecutive hours. Change in AS over time was determined using repeated-measures mixed linear modeling with each patient treated as a random effect and therapy group, time, and the interaction of therapy group and time as fixed effects. To determine individual associations between AS, MV mode, and oxygen therapy, multivariable ordinal regression models for AS-related variables and Cox proportional hazard models with AS as time-dependent covariate were used adjusting for Acute Physiology and Chronic Health Evaluation III (APACHE III) score, primary diagnosis, and reason for MV.

In addition, sensitivity analysis was performed by excluding patients who died during the study period and repeated after excluding both patients who died and patients who were discharged form ICU before day 7 because of the possible competing risk of such events with time to spontaneous ventilation. Furthermore, a final sensitivity analysis was performed after excluding patients with baseline AS of 0, where AS could not be improved further. The multivariable ordinal regression models for AS-related variables were reassessed, and a multivariable logistic regression model for the improvement of AS from baseline was also conducted. All analysis was performed by using SPSS version 19.0 (SPSS,

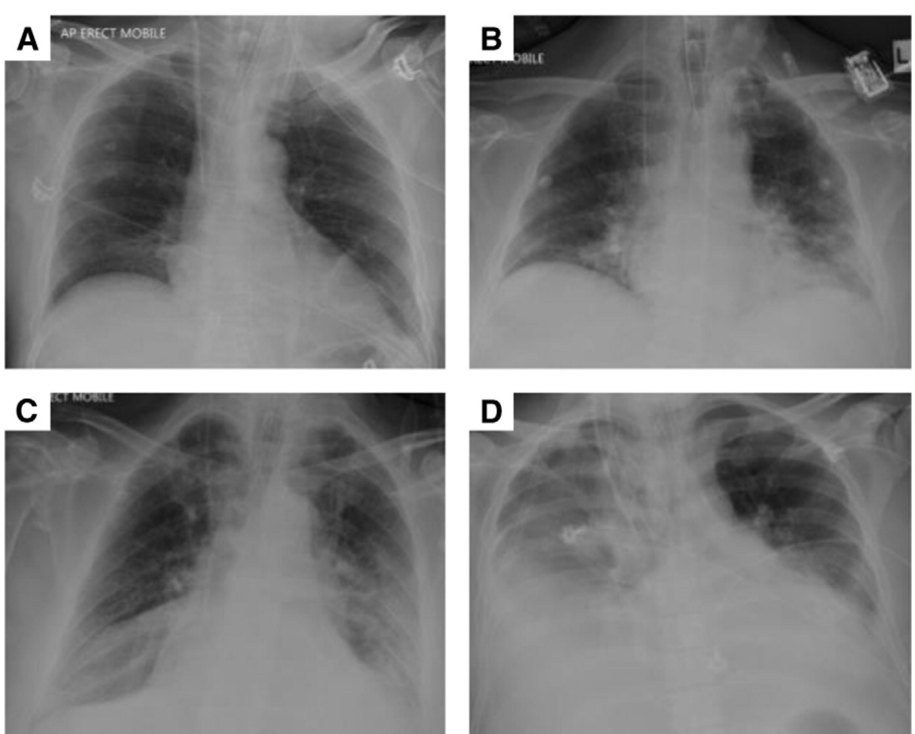

Fig. 1. A typical chest x-ray image for each AS: 1, plate-like atelectasis or slight infiltration (A); 2, partial atelectasis (B); 3, lobar atelectasis (C); and 4, bilateral lobar atelectasis (D).