Usefulness of radiological signs of pulmonary congestion in predicting failed spontaneous breathing trials

Ana Carolina Peçanha Antonio1,2, Cassiano Teixeira2, Priscylla Souza Castro2,3, Ana Paula Zanardo1, Marcelo Basso Gazzana2, Marli Knorst4

ABSTRACT

Objective: Inspiratory fall in intrathoracic pressure during a spontaneous breathing trial (SBT) may precipitate cardiac dysfunction and acute pulmonary edema. We aimed to determine the relationship between radiological signs of pulmonary congestion prior to an SBT and weaning outcomes. Methods: This was a post hoc analysis of a prospective cohort study involving patients in an adult medical-surgical ICU. All enrolled individuals met the eligibility criteria for liberation from mechanical ventilation. Tracheostomized subjects were excluded. The primary endpoint was SBT failure, defined as the inability to tolerate a T-piece trial for 30-120 min. An attending radiologist applied a radiological score on interpretation of digital chest X-rays performed before the SBT. Results: A total of 170 T-piece trials were carried out; SBT failure occurred in 28 trials (16.4%), and 133 subjects (78.3%) were extubated at first attempt. Radiological scores were similar between SBT-failure and SBT-success groups (median [interquartile range] = 3 [2-4] points vs. 3 [2-4] points; p = 0.15), which, according to the score criteria, represented interstitial lung congestion. The analysis of ROC curves demonstrated poor accuracy (area under the curve = 0.58) of chest X-rays findings of congestion prior to the SBT for discriminating between SBT failure and SBT success. No correlation was found between fluid balance curve = 0.58) of chest x-rays findings of congestion prior to the SBT for discriminating between SBT failure and SBT success. No correlation was found between fluid balance

Conclusions: Radiological findings of pulmonary congestion should not delay SBT indication, given that they did not predict weaning failure in the medical-surgical critically ill population.

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Keywords: Radiography; Pulmonary edema; Ventilator weaning.

INTRODUCTION

Weaning from mechanical ventilation (MV) is a gradual process that involves withdrawing the patient from the ventilator and removing the endotracheal tube. The weaning process can account for as much as 42% of the total duration of MV.1-3 MV is associated with significant complications that are time-dependent in nature, prolonged intubation resulting in an increased incidence of complications, such as ventilator-associated pneumonia and increased mortality.4,5 However, impetuous attempts at weaning from MV are also hazardous. A failed attempt at extubation is associated with an 8-fold increase in mortality risk.6 Therefore, the clinical challenge is to balance aggressiveness against safety.

Large clinical trials conducted in the 1990s showed that clinicians frequently miss opportunities to wean patients from MV. The fact that most patients (75%) are extubated on the same day on which the weaning process is initiated suggests that the process can be initiated earlier, misconceptions and “slow” weaning procedures accounting for delayed weaning.7,8

Weaning-induced cardiac dysfunction is recognized as an important cause of weaning failure.9 During a spontaneous breathing trial (SBT), an abrupt drop in intrathoracic pressure during inhalation tends to increase the systemic venous return pressure gradient and to decrease the left ventricular (LV) ejection pressure gradient, thus resulting in increased LV filling pressure. A marked increase in the work of breathing can result in increased cardiac work and myocardial oxygen demand.9,10

Chest X-rays (CXR) are commonly used in order to detect pulmonary edema. Radiographic signs that suggest accumulation of fluid in the lung interstitium or alveolar space include vascular redistribution, septal lines (Kerley’s A and B lines), interlobular septal thickening, peribronchial cuffing, bilateral opacities (“bat wing” pattern), air bronchogram, and pleural effusion. In patients with pulmonary edema due to heart failure, the heart is commonly enlarged.11 Some experts recommend that CXRs be routinely taken before an SBT in order to confirm “disease reversal”, discard fluid overload, and define eligibility.2,14-15 However, these criteria have been neither defined nor prospectively evaluated in a randomized controlled trial. In addition, CXR accuracy is significantly limited by acquisition techniques and clinical issues that override standardization procedures, especially in the ICU.11,12
Shochat et al.\(^{(16)}\) developed a radiographic score (RS) to evaluate lung fluid content in individuals with acute heart failure following acute myocardial infarction. In that prospective single-center study, the novel RS was found to be able to assess lung edema severity and its changes over time, as well as correlating significantly with patient clinical status.

In a recent study, our research group showed loss of lung aeration during the weaning process, as estimated by bedside lung ultrasound; however, the presence of interstitial syndrome before initiation of weaning from MV failed to distinguish between individuals in whom weaning was successful and those in whom weaning failed.\(^{(17)}\) We assumed that CXR findings of lung edema also lack predictive power to discriminate between weaning success and weaning failure; therefore, radiological signs of pulmonary congestion should not delay the decision to initiate the weaning process. The objective of the present study was to assess prospectively whether radiological signs of pulmonary congestion prior to an SBT correlated with weaning outcomes in a heterogeneous group of mechanically ventilated patients.

**METHODS**

Between January of 2011 and March of 2013, nonconsecutive patients over 18 years of age and undergoing invasive MV for at least 24 h were selected from among those treated at a semiclosed medical-surgical ICU in a private hospital, with 24-h intensivists. Patients with a tracheostomy were excluded. The local research ethics committee approved the study and waived the requirement for informed consent. The presence of diastolic or systolic LV dysfunction (the latter condition being defined as an ejection fraction < 45%) was documented based on a formal echocardiogram report dated up to six months prior to admission. A diagnosis of COPD was based on history, physical examination, CXR, and previous pulmonary function tests, if available.

Shochat et al.\(^{(16)}\) found a mean raise of 4.8 points in the RS of individuals who developed overt acute heart failure during hospitalization, whose mean baseline values were 0.6. Hence, our final sample of 170 subjects available for the analysis of the primary outcome had a 99% power to detect the same difference between SBT-success and SBT-failure groups, at a two-sided alpha level of 0.05.

The results were expressed as mean ± SD, median (interquartile range [IQR]), and proportions, as appropriate. The normal distribution of the various parameters was investigated by the distribution of data and using the Kolmogorov-Smirnov test. We used the Student’s t-test or the Mann-Whitney U test to compare continuous variables, and the chi-square test or Fisher’s exact test to compare proportions, as appropriate. A ROC curve was generated based on predictive RS results and SBT outcomes. Spearman’s correlation coefficient was determined in order to correlate fluid balance and RS results. The analyses were performed with the use of the IBM SPSS Statistics software package, version 20.0 (IBM Corporation, Armonk, NY, USA).

**RESULTS**

We obtained complete data for 170 weaning procedures. Overall, SBT failure occurred in 28

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(16.4%). Table 2 shows the baseline characteristics of the cohort according to the outcome. Patients who were successfully extubated had been intubated for a shorter duration than had those who were not (median duration of MV: 4 days vs. 6 days; \( p = 0.003 \)). In our cohort, 133 patients (78.3%) were extubated at first attempt. Sepsis of any source was the main reason for MV initiation, in approximately 40% of all individuals in both groups. Approximately 11% of the individuals were intubated owing to congestive heart failure, and the same amount had a pre-existing diagnosis of systolic LV dysfunction.

The RS results were similar between SBT-failure and SBT-success groups (median = 3 [IQR: 2-4] vs. 3 [IQR: 2-4]; \( p = 0.15 \)), which corresponded to interstitial lung congestion. The analysis of the ROC curve showed that the RS prior to a T-piece trial had poor accuracy in discriminating between SBT failure and SBT success (area under the curve = 0.58; \( p = 0.2 \); Figure 2). There was no correlation between fluid balance 48 h prior to the SBT and RS results (\( \rho = -0.13; \ p = 0.1 \)).

**DISCUSSION**

In a heterogeneous cohort of mechanically ventilated patients who were candidates for a SBT, we found no association between radiological signs of pulmonary congestion indicated by the RS and SBT outcomes. Our study suggests that incorporating radiological estimations of lung edema as a readiness criterion for weaning from MV potentially retards it, as long as interstitial pulmonary congestion was observed on SBTs. To the extent of our knowledge, this is the first report encompassing such a topic.

The rationale behind delaying an SBT due to radiological signs of pulmonary congestion might be the belief that MV patients could not succeed in a T-piece trial unless they were "dry" again, given that cardiorespiratory interactions under negative pressure promote increases in both LV preload and afterload. However, a myriad of changes in respiratory mechanics and in the cardiovascular system related to weaning failure is not evident until clinical manifestations of distress appear, which promptly demand interruption of the trial or reintubation. Fluid balance cannot predict SBT outcomes in a slightly larger, mixed medical-surgical

**Table 1.** Radiological score parameters and values.*

| Parameter                                  | Value |
|--------------------------------------------|-------|
| Redistribution of lung vessels             |       |
| No                                         | 0     |
| Yes                                        | 1     |
| Width of the cardiac silhouette > 60%      |       |
| No                                         | 0     |
| Yes                                        | 1     |
| Peribronchial cuffing                      |       |
| No                                         | 0     |
| Yes                                        | 1     |
| New pleural effusion                       |       |
| No                                         | 0     |
| Unilateral                                 | 1     |
| Bilateral                                  | 2     |
| Kerley’s A, B, or C lines                  |       |
| None                                        | 0     |
| Uncertain                                  | 1     |
| Definite                                   | 2     |
| Lung opacity                               |       |
| None                                       | 0     |
| Lung opacity                               | 1     |
| Ground-glass opacity                       | 2     |
| “Bat wing” pattern                         | 3     |

Based on Shochat et al.\(^{(16)}\) *Severity of pulmonary edema was determined as follows: normal chest X-ray, 0-1 points; interstitial lung congestion, 2-4 points; and mild, moderate, and severe alveolar edema, respectively, 5-6 points, 7-8 points, and 9-10 points, respectively.*

**Figure 1.** In A, a chest X-ray of a 68-year-old female patient shows peribronchial cuffing and opacity in a "bat wing" pattern, revealing edema, compounding a radiological score of 4 points, characterized as interstitial lung congestion.\(^{(16)}\) In B, a chest X-ray of a 57-year-old male patient shows a cardiothoracic ratio > 60%, peribronchial cuffing, lung vessel redistribution, Kerley’s A line, and lung opacity, resulting in a score of 5 points, characterized as mild alveolar edema.\(^{(16)}\)
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ICU population either, perhaps being more relevant for COPD patients, as we published previously. An observational study involving 100 patients immediately before a T-piece trial demonstrated that baseline levels of brain natriuretic peptide—a surrogate marker of congestive heart failure—were moderately elevated exclusively in SBT-failure individuals, who eventually failed owing to cardiac dysfunction. Moreover, overtreatment based on isolated CXR interpretations might be harmful in terms of weaning readiness.

An interobserver agreement study examined the extent to which medical intensivists and a radiologist could agree on whether a CXR revealed diffuse bilateral infiltrates for the diagnosis of ARDS or not and concluded that intensivists without formal consensus training can achieve moderate levels of agreement. Accordingly, in real clinical practice, an expert radiological opinion is not immediately available, and delaying the weaning process based upon poor interpretations of CXRs might be even more questionable. Since the physicians in our study were not aware of the most recent CXR results, we were unable to prove that hypothesis.

A systematic review highlighted the safety of abandoning routine CXRs in favor of a more restrictive approach. Arguments for adopting a restrictive approach included varying interpretations of CXRs depending on clinician and patient factors, low incidence of clinically unsuspected abnormalities, potential harm arising from unnecessary treatment of minor or false-positive findings, costs, radiation exposure and adverse events arising from the repositioning of the patient to obtain CXRs. Likewise, the importance of negative CXR findings for workflow, efficiency, and clinical decision-making might be overestimated. A study collecting the opinions of experienced ICU physicians regarding the appropriateness of performing routine CXRs in various situations encountered in adult ICUs showed there was no consensus regarding the usefulness of obtaining a routine CXR prior to extubation.

It should be pointed out that our study consisted of a relatively small number of patients and absolute number of failure events, with a high prevalence of elderly patients and a low prevalence of systolic LV dysfunction. Nonetheless, our sample had the same

| Characteristic                  | SBT success (n = 142) | SBT failure (n = 28) | p     |
|--------------------------------|-----------------------|----------------------|-------|
| Age, years                     | 76 (66-84)            | 67 (52-80)           | 0.15  |
| Female gender                  | 62 (43.7)             | 13 (46.4)            | 0.79  |
| APACHE II score                | 21 ± 6.9              | 23 ± 7.8             | 0.16  |
| SOFA score                     | 5 (3-9)               | 5 (2-10)             | 0.50  |
| BMI, kg/m²                     | 25 (23-28)            | 25 (22-29)           | 0.97  |
| RSBI, f/V<sub>T</sub>          | 53 (41-75)            | 52 (36-71)           | 0.94  |
| MV duration, days              | 4 (2-6)               | 6 (4-11)             | 0.003 |
| Fluid balance 48 h prior to the SBT, mL | 1,219 ± 2,912 | 1,838 ± 1,896 | 0.48  |

Table 2. Characteristics of the study cohort (N = 170)."
Sensitivity AUC = 0.58

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