Electrical Impedance Tomography for fine tuning of Mechanical Ventilation in a patient hospitalized in a Pediatric Intensive Care Unit

Camila Cestaro[1], Letícia Corrêa[2]

[1]Training Coordinator at Timpel, [2]Training Instructor at Timpel

Introduction

Electrical impedance tomography (EIT) is a noninvasive, radiation-free monitoring tool that allows real-time imaging of ventilation. EIT is the only bedside method that allows repeated, noninvasive measurements of regional changes in lung volumes[1]. For this and other characteristics, its use in patients under ventilatory support brings great benefits to the patient and caregiver, allowing a more precise management of the ventilatory adjustments, besides the immediate perception of the patient's response to this adjustment.

Within this context, a patient hospitalized in a Pediatric Intensive Care Unit with the diagnosis of Single Left Ventricle, prematurity of 26 weeks gestational age at birth and bronchodysplasia was monitored with Enlight 1800 (Timpel, Brazil).

Single ventricle-type congenital heart disease consists of a spectrum of malformations in which there is significant hypoplasia of either the right or left ventricle with no anatomical or functional capacity for viability of a 2-ventricle system. The condition is severe and may be fatal, and the treatment consists of strategies for its correction in three surgical steps, whose improvements in the accomplishment of these techniques and postoperative management have increased the survival of the patients with this cardiopathy. The first, Blalock-Taussig surgery, connects the aorta to the pulmonary artery and is performed in the first days of life. At 4 or 6 months of age, according to its evolution, the patient goes through the second stage, Glenn's surgery, where the pulmonary artery and the superior vena cava are connected. Finally, Fontan surgery, which establishes a passive pathway for systemic venous return to the pulmonary circulation[2].

The patient monitored with Enlight 1800 was one year old, fully dependent on mechanical ventilation.

Case Report

Patient hospitalized since birth, due to congenital heart disease type Single Left Ventricle, had undergone Blalock-Taussig surgery in the first month of life, was under invasive mechanical ventilation (IMV), with recurrent extubation failures, waiting for tracheostomy and definitive cardiologic surgical management. It was intubated, under IMV in PRVC mode with PEEP 7cmH2O, PPeak 19cmH2O, Insp Time 0,5s, RR 20 / 30bpm, VT 65ml. He presented in occasional cycles, double trigger episodes (Figure 4).

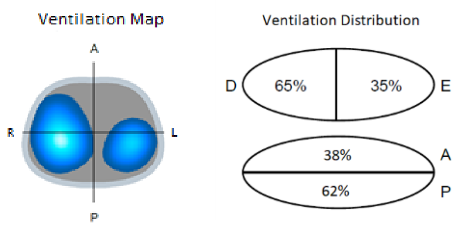

Figure 1: Initial Ventilation Distribution

The multidisciplinary team that followed the case, opted to reduce the PEEP to 6cmH2O, since the patient had dominance in the posterior ventilation.

By reducing PEEP, the left anterior region presented loss of ventilation while the posterior region showed a bilateral gain (Figure 2a). The ventilation distribution was in A / P: 36% / 64%.

After this first change, it was decided to reduce PEEP again to 5cmH2O, however, the patient lost ventilation in the posterior region (Figure 2b).

During the changes in adjustments, it was decided to maintain PEEP at 6cmH2O, with recovery of ventilation in the lost area.

Another adjustment was the adequacy of Insp Time to correct the Double Trigger, increasing it from 0.5s to 0.65s. At this time, there was improvement of the right / left distribution (R / L: 60% / 40%).

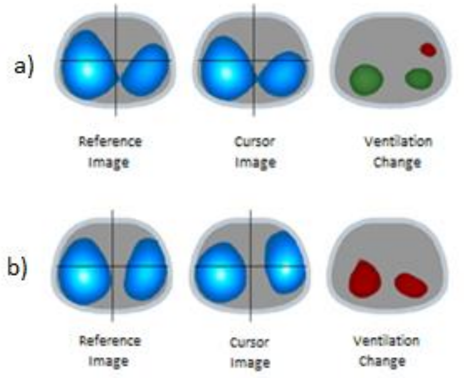

Figure 2.a): Ventilation change after reducing PEEP from 7 to 6cmH2O. There was a gain in ventilation in the posterior region, probably due to relief of hyperdistension. b) After reducing to PEEP of 5cmH2O, the posterior region lost ventilation, suggesting the appearance of collapse.

To evaluate possible alterations in the distribution of ventilation, the patient was positioned in Right Lateral Decubitus (RLD), when it was possible to visualize a gain in the End Expiratory Lung Volume (EELV) in the left region, with R / L ratio: 55% / 45% (Figure 3).

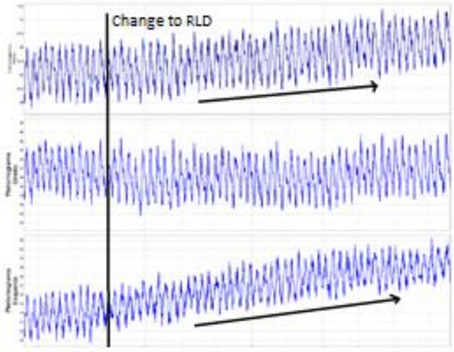

Figure 3: Plethysmogram behavior after change the decubitus

Discussion

Electrical Impedance Tomography allows the observation of the plethysmogram to evaluate the changes occurring in the pulmonary volumes. The wave amplitude variation corresponds to the Tidal Volume (VT) and in the baseline, is attributed to variations in Functional Residual Capacity (FRC) or End Expiratory Lung Volume (EELV)[3].

The first reduction of PEEP in this patient demonstrated the gain of posterior ventilation, probably related to the relief of hyperdistension in this region. However, in the second reduction, the loss of ventilation in the same region suggested that PEEP of 5cmH2O would be insufficient and could lead to collapse.

Double triggering consists of the ventilator delivering two consecutive breaths in response to patient respiratory muscle effort, that is, it occurs when patient effort triggers two breaths in a row. In such cases, patient neural inspiratory time is longer than the ventilator inspiratory time[4].

The differential of monitoring asynchrony by EIT is to be able to observe the effect of breath stacking, which consists of the accumulation of tidal volume due to asynchrony. This stacking may result in greater distention of the lung parenchyma, with corresponding elevation of alveolar and airway pressures[4].

Notice below the amplitude of the plethysmogram in the Double Trigger cycle.

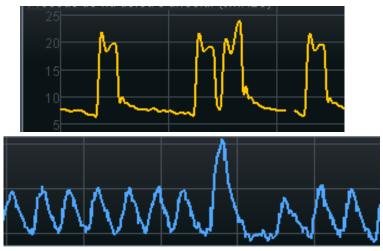

Figure 4: Amplitude variation of plethysmogram during Double Trigger

Increasing the Inspiratory Time corrects this asynchrony, equating the patient´s inspiratory neural time with the mechanical ventilator.

It is known that the positioning may also have an effect on pulmonary volumes and gas exchange, which has been observed in several studies comparing prone and supine position, however, studies that indicate these changes in lateral decubitus are limited[5-7]. Gravitational effects may result in regional changes in FRC variations and ventilation distribution, and it is suggested that non dependent regions are prone to improved EELV[8].

In this case report it was possible to observe the importance of EIT for the fine adjustments of mechanical ventilation. In one hour of monitoring it was possible to reduce PEEP, optimizing ventilation distribution; correct the breath stacking asynchrony, that could lead to lung injury and improve ventilation in the left lung without hyperdistending the right lung.

References

1. Costa, E.L.V.; LIMA, R.G.; AMATO, M.B.P. Electrical Impedance Tomography. Current Opinion in Critical Care 2009, 15:18-24

2. Liu, M., *et al.* Longitudinal Assessment of Outcome from Prenatal Diagnosis Through Fontan Operation for Over 500 Fetuses With Single Ventricle-Type Congenital Heart Disease: The Philadelphia Fetus-to-Fontan Cohort Study. J Am Heart Assoc. 2018 Oct 2;7(19).

3. Victorino JA, Borges JB, Okamoto VN, Matos GF, Tucci MR, Caramez MP, Tanaka H, Suarez Sipmann F, Santos DC, Barbas CS, Carvalho CR, Amato MB. Imbalances in regional lung ventilation: a validation study on electrical impedance tomography. Am J Respir Crit Care Med 2004;169:791–800.

4. HOLANDA, M.C., et al. Patient ventilator asynchrony. J Bras Pneumol, 2018; 44(4): 321-333

5. Bhat RY, Leipala JA, Singh NR, Rafferty GF, Hannam S, Greenough A. Effect of posture on oxygenation, lung volume, and respiratory mechanics in premature infants studied before discharge. Pediatrics 2003;112:29-32

6. Leipala JA, Bhat RY, Rafferty GF, Hannam S, Greenough A. Effect of posture on respiratory function and drive in preterm infants prior to discharge. Pediatr Pulmonol 2003;36:295–300.

7. Wolfson MR, Greenspan JS, Deoras KS, Allen JL, Shaffer TH. Effect of position on the mechanical interaction between the rib cage and abdomen in preterm infants. J Appl Physiol 1992;72:1032–1038.

8. Van der Burg PS, Miedema M, de Jongh FH, Frerichs I, van Kaam, AH. Changes in lung volume and ventilation following transition from invasive to non-invasive respiratory support and prone positioning in preterm infants. Pediatr Res 2015;77:484–488.