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Use of the Electrical Impedance Segmentography system in a neonatal respiratory distress case

Pasqua Maria Betta, Valentina Fatuzzo, Angela Lanzafame, Agnese Castro, Alessandro Giallongo, Sciacca Pietro

ABSTRACT

Introduction: The Electrical Impedance Segmentography system (EIS) is a technique able to detect any kind of dishomogeneities between the pulmonary segments and to study the air distribution and the regional current volumes, by monitoring the impedance in the four pulmonary quadrants, in a continuous, non-invasive, fast and low-cost manner. We used this method for the management of a patient born at term with respiratory distress. Case Report: On admission to the ward, a non-invasive respiratory assistance was set up. The chest X-ray showed a massive opacity of the left hemithorax as due to a pulmonary atelectasis. Therefore, we decided to administer surfactant by the ET tube using the INSURE technique, with a slight, clinical and radiological improvement. At the same time, we started to monitor our patient ventilation using the EIS: in agreement with the radiological findings, it revealed an initial exclusion of the left, lower, pulmonary lobe and a progressive lung recruitment. It also showed immediate changes of the EIS patterns after every therapeutic maneuver (airway aspiration, surfactant administration, PEEP variations). On the 10th day of life a clinical stabilization and a complete radiological resolution were achieved, so the baby was weaned from the respiratory assistance. Conclusion: The presented case, in agreement with the literature, shows that the EIS can represent a safe and effective guide to set up the mechanical ventilation in newborns. In fact, it supplies a non-invasive and immediate assessment of ventilation, highlighting the poor ventilated areas and allowing immediate therapeutic adjustments.

Keywords: Electrical impedance segmentography, Monitoring, Respiratory distress syndrome, Surfactant

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INTRODUCTION

The onset of lung injuries like patchy ventilation, pulmonary oedema, pneumothorax and atelectasis represent a challenging problem in newborns affected by severe respiratory distress or suffering from surgical diseases who need a mechanical ventilation for a long time. A part from the traditional and commonly used monitoring tools, the Electrical Impedance Segmentography (EIS) has recently received much research interest as a reliable means to optimize the respiratory function in critically ill neonates admitted in the neonatal intensive care units (NICUs) [1]. Evolution of an older, similar, monitoring technique, the Electrical Impedance tomography (EIT), the EIS is a new, non-invasive, fast, low-cost technique able to study the air distribution and the regional current volumes of lungs. By monitoring the lung impedance in the 4 pulmonary quadrants, it can continuously detect any kind of dishomogeneities between the pulmonary segments, guiding all therapeutic adjustments [2]. Specially designed for neonatal and pediatric bedside use, it displays the impedance data recorded by 10 chest electrodes as values, waveforms and parameters. The system works on both spontaneously breathing and ventilated patients [3]. The vulnerable population of preterm infants is particularly suited for EIS monitoring, especially because it can supply information about the patient response to all therapeutic maneuvers, allowing a more accurate ventilation management. Therefore it offers several advantages compared to traditionally used imaging techniques. In the past, the principle obstacle for the routine application of the EIT in critically ill neonates came from the difficult placement of many electrodes around the neonatal chest with equidistant spacing, which required extensive handling. Recently this limit has been overcome by the use of the EIS, which does not request a high number of electrodes throughout the chest, nor a meticulous care for a correct placement, making the technique suitable also for small patients [4].

CASE REPORT

We used the EIS to improve the ventilatory management of a patient born at term (38+1 weeks gestational age), at our Hospital by caesarean section due to previous scar and suspected meconium ileus (ultrasound at 36+5 gestational weeks decribed as colon hypecogencity), birth weight 2970 gr, Apgar Index 1' 9, 5' 10. The patient was admitted to our NICU to investigate suspected meconium ileus. On admission to the ward she presented a severe respiratory distress with intercostal retractions, nasal flaring, exipratory grunt (Sat.O2 88%, Silverman score 7)., a non-invasive respiratory assistance (n-CPAP 5 cm H_2O) was set up. The first capillary blood gas analysis showed a respiratory acidosis (ph 7.17, pCO_2 68.6 mmHg, pO_2 30.2 mmHg, HCO_3^- 18.1 mmol/L, BE -7.2 mmol/L). The chest X-ray showed a massive opacity of the left hemithorax, as due to a pulmonary atelectasis (Figure 1). At the same time, we started to monitor our patient ventilation features using the EIS. In agreement with the radiological findings, it revealed an initial exclusion of the left lower pulmonary lobe (Figure 2).

Therefore, we decided to use the INSURE technique, consisting of intubation, enodotracheal surfactant administration through a 5 Fr feeding tube (pig lungs surfactant extract 200 mg/kg) and rapid extubation. After extubation patient was given non-invasive respiratory support n-IPPV with the following parameters PEEP 5 cmH_2O, PIP 15 cmH_2O, FR 45/min, Ti 0.5 sec, FiO_2 25%. Surfactant administration led to a slight clinical improvement and immediate changes of the EIS pattern after each therapeutic maneuver (airway aspiration, surfactant administration, PEEP variations), with a progressive lung recruitment (Figure 3). Capillary blood gas analysis improved (pH 7.31, pCO_2 53 mmHg, pO_2 36.8 mmHg, HCO_3^- 23.4 mmol/L, BE -0.4) Chest X-Ray after surfactant administration revealed a reduced opacity of the left lung. Then, after 3 days, she was switched to n-CPAP 5 cmH_2O, FiO_2 21%, Sat. O_2 97%). On the 10th day of life a clinical stabilization and a complete radiological resolution were achieved (Figure 4), so the baby was weaned from the respiratory assistance. Inflammatory markers (C reactive protein) and microbiological evaluations all resulted negative. Concerning the suspected meconium ileus, the newborn had a spontaneous meconium emission within the first 24 hours of life and cystic fibrosis was excluded by negative sweating test and genetic analysis. The newborn was discharged on the 18th day of life, 2900 gr weight.

Figure 1: Chest X-ray at admission, left pulmonary atelectasis.

Figure 2: EIS pattern at admission. Impedence in upper left, upper right, lower left, lower right. Lower left pulmonary lobe atelctasis, with no impedence signal.

Figure 3: EIS pattern after therapeutic maneuver, with a progressive lung recruitment. It shows an increasing trend in impedence in lower left pulmonary lobe after surfactant administration.

DISCUSSION

Electrical Impedance Tomography (EIT) is a radiation free, bedside method, introduce by B. H. Brown in 1983. It allows functional regional chest monitoring [5]. It requires 16 electrodes put around chest wall. EIT images are obteined by changes of the tissue composition (alveolar fluid, fibrosis, atelectasis, pneumothorax) which induce a change in regional bioimpedance. Electrical currents are conducted thorugh pairs of electrodes around the thorax, creating a voltage profile. Then, the bioelectrical impedance between each electrode pair is calculated: the resulting values are used to reconstruct a cross sectional Figure. To be able to provide a high-resolution Figure, EIT requires a complex system of processors and software. Calculating the impedance differences in relation to a reference, these Figures are then represented by a color coding and percentages. An EIT waveform is then defined as a sequence of impedance change values over the time in different regions of interest (ROI), where Figure pixels are chosen to reflect regional changes associated with relevant effects. Hence, EIT is able to supply information about global and local ventilation activity, picturing a map of ventilation distribution [6]. However, the important limit of EIT is that only regions of the thorax that change

Figure 4: Chest X-ray, If compared to the previous one, it shows resolution of pulmonary left atelectasis.

their impedance over the time will be represented by the EIT Figures. Moreover, in newborns and in premature babies in particular, its use is limited by the small size of the thorax, since it needs many electrodes around the chest for obtaining the required Figures [7].

Electrical impedance segmentography (EIS) is a non-invasive, bedside technique allowing a continuous record of regional air lung distribution. It differs from EIT because it determines impedance changes in four quadrants of the thorax upper left, upper right, lower left, lower right) and also allows quantification of impedance changes of the lung expressed as absolute tidal volumes.. In contrast to the attempts of EIT to produce electrical impedance high resolution figures of cross sections of the chest, the EIS method focuses on detecting and monitoring clinical treatable inhomogeneities as they occur in the upper and lower, left and right segments of the chest, avoiding the need of a high number of electrodes throughout the chest and making the technique suitable also for small patients [8].

Infants admitted in NICUs most commonly present with a respiratory distress syndrome (RDS). Prematurity, as well as condition as the transient tachypnea of the term newborn and the meconium aspiration syndrome, can cause a reduction of tidal volume and functional residual capacity (FRC) and often request a respiratory assistance by mechanical ventilation and sometimes endotracheal intubation. Chest X-ray, pulse oximetry, end tidal CO_2 and blood gas analysis are the most commonly tools used to understand the evolution of the respiratory picture of small patients at NICUs. Nevertheless, a continuous monitoring of the regional pathological processes ongoing within the lungs of these patients, included the intubation complications, the side effects of an inadequate ventilation, as well as the positive effects of every therapeutic maneuver, is still missing until today. There are several indications to monitor the lungs of infants who need a respiratory support: to study the lung physiology of infants and achieve a less harmful ventilation, to detect episodes of apnoea, abnormal positioning and dislocation of the ET tube, the onset of a pneumothorax and to ensure a homogenous distribution of surfactant throughout the airways [9].

For its technical characteristics EIS may represent a reliable tool to monitor lung recruitment and optimize the ventilation based on the needs and the features of the single patient. In our case we used the EIS to monitor continuously the lung function of a patient born at term with a severe RDS who has needed to be supported by mechanical ventilation and surfactant administration at birth. On admission to the ward, EIS simply confirmed the pulmonary radiological findings, before and after the surfactant administration. Nevertheless, over the days, it supplied continuous information about the progressive recruitment of the left lung and guided the ventilation management in relation to the patient needs, until she was definitively weaned from the respiratory support and put on spontaneous breathing.

Even though our experience in monitoring the respiratory function of patients admitted to our NICU by EIS is still limited, the results achieved until today are encouraging and consistent with the recent literature. Moreover, in our opinion, EIS could be a reliable and important means of monitoring the pulmonary ventilation of all patients who require a long term respiratory support, included the surgical patients during the postoperative period.

CONCLUSION

The presented case, shows that the EIS, highlighting the poor ventilated areas and allowing immediate therapeutic adjustments. can represent a safe and effective guide to set up the mechanical ventilation in newborns with RDS.

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Author Contributions
Pasqua Maria Betta – Substantial contributions to conception and design, Drafting the article, Revising it critically for important intellectual content, Final approval of the version to be published
Angela Lanzafame – Acquisition of data, Drafting the article, Revising it critically for important intellectual content, Final approval of the version to be published
Alessandro Giallongo – Acquisition of data, Drafting the article, Final approval of the version to be published
Valentina Fatuzzo – Analysis and interpretation of data, Drafting the article, Final approval of the version to be published
Agnese Castro – Analysis and interpretation of data, Drafting the article, Final approval of the version to be published
Pietro Sciacca – Substantial contributions to conception and design, Revising it critically for important intellectual content, Final approval of the version to be published

Guarantor of Submission
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Written informed consent was obtained from the patient for publication of this case report.

Conflict of Interest

Authors declare no conflict of interest.

Data Availability

All relevant data are within the paper and its Supporting Information files.

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