SenTec EIT: How it could help in the COVID-19 outbreak

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Abstract

This short paper will briefly describe how SenTec EIT could help in the management of patients with a moderate to severe presentation of COVID-19 that are in need of ventilator support

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SenTec EIT: brief description

SenTec EIT is based on the principles of electrical impedance tomography (EIT), where weak alternating currents are applied to the body and travel along the paths of least resistance thereby creating electric potentials at the body surface. These potentials are being measured continuously by electrodes placed on the thoracic skin and turned into tomographic images of lung function. To this end, a belt-like disposable textile patient interface is fastened around the patient‘s chest. Its embedded electrodes measure the electrical impedance distribution within the thorax. Since intra-thoracic impedance varies with ventilation, the recorded impedance changes can be used to generate real-time tomographic images, which allow the monitoring of ventilation in different lung regions.

How SenTec EIT can help

In contrast to radiological methods like CT, SenTec EIT is a non-invasive radiation-free medical device that allows continuous monitoring of the ventilation distribution within the lungs at the bedside. The continuous monitoring may promptly identify the onset of complications (e.g. increasing atelectasis or over-distention), determine the usefulness of therapeutic interventions in real time or assess the success of processes such as prone positioning or weaning. With the color-coded stretch images (see Fig. 1a), it is readily clear where ventilation is taking place within lung regions. Moreover, SenTec EIT images are provided with a unique lung model contour, which eases interpretation and allows the introduction of the useful concept of Silent Spaces (see Fig. 1b), as detailed below.

(a) Stretch Image displaying the distribution of ventilation within the lung contours. Progression from grey to violet represents increasing ventilation.

(b) Silent Spaces Image displaying minimally or not ventilated lung areas in pink. The white dot and grey hollow circle represent the current and default Center of Ventilation, respectively.

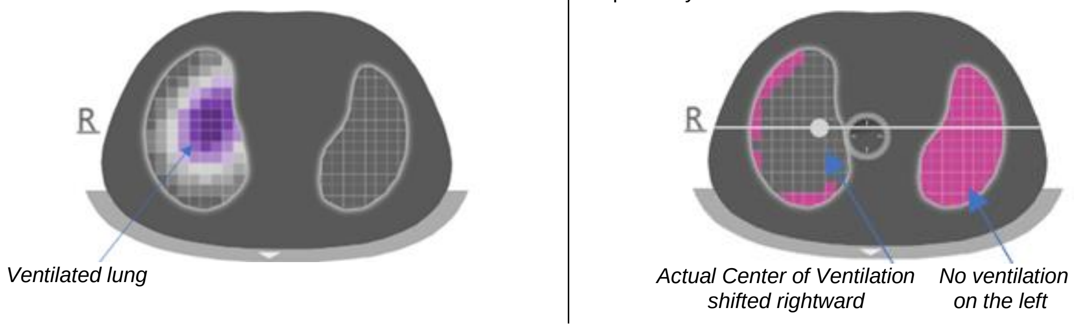

Figure 1**.** Illustrative example of SenTec EIT data from a patient with a mal-positioned endotracheal tube. Stretch Image (a) and Silent Spaces Image (b) reveal that the left lung shows no ventilation with the current Center of Ventilation shifted rightwards. Unpublished data.

For ventilated patients, it is important to optimize PEEP or the driving pressure to the personal needs of individual patients. SenTec EIT offers the possibility to titrate PEEP based on the concept of Silent Spaces, which may appear a more straightforward approach than the more common pressure-volume (P-V) curves. Basically, Silent Spaces represent those regions within lung areas that exhibit little or no ventilation. They are identified as those regions where the impedance change during a breath is minimal with respect to the maximum tidal impedance change within the whole lung areas. The rest of the lung area is defined as the Functional Lung Space.
A unique feature of SenTec EIT is the continuous detection of the patient position, which enables the categorization of Silent Spaces into dependent and non-dependent ones with respect to gravity. This allows an easy analysis of ventilation distribution patterns and their changes with respect to the supine or prone positions of the patient[1]. The dependent Silent Spaces tend to decrease with increasing PEEP, suggesting reduction of areas that are collapsed or filled with fluid. However, if PEEP gets too high, the non-dependent Silent Spaces tend to increase, suggesting that the tissue starts to be over-distended. This observation can be used to titrate PEEP. Indeed, tracking the changes in Silent Spaces at different PEEP levels can assist the physicians in finding personalized PEEP that minimizes both collapsed and over-distended areas and enables lung protective ventilation. The analysis of Silent Spaces may

[1] See e.g. http://www.swisstom.com/wp-content/uploads/prone-positioning_2.0.pdf

suggest other interventions as well. For example, if Silent Spaces are predominantly non-dependent, then reducing tidal volume or inspiratory pressure or changing patient position may be taken into consideration. If they are mainly dependent, then recruitment maneuvers and position changes should rather be considered. If Silent Spaces are extended significantly in both upper and lower regions, then probably prone positioning, ventilation with a smaller pressure amplitude or ECMO should be the options to evaluate[2].

As explained in Spadaro et al.[3], the traditional pressure-volume (P-V) curve reflects global characteristics, but changes at the regional level may remain undetected. In their study on 14 patients with acute hypoxemic respiratory failure and acute respiratory distress syndrome the dynamic variation of Silent Spaces not only correlated well with recruitment assessed with the standard method of P-V curve, but also provided additional perspective. With the words of the authors: “The use of Silent Spaces as a bedside method to determine the recruitment of functional lung volume has many advantages compared with the P-V curve because the monitoring is breath-wise and continuous, providing local information. Furthermore, it does not require the use of high doses of sedatives or muscle relaxants.” Fig. 2 adapted from the same article shows that the reduction in Silent Spaces is accompanied by an increased homogeneity of ventilation.

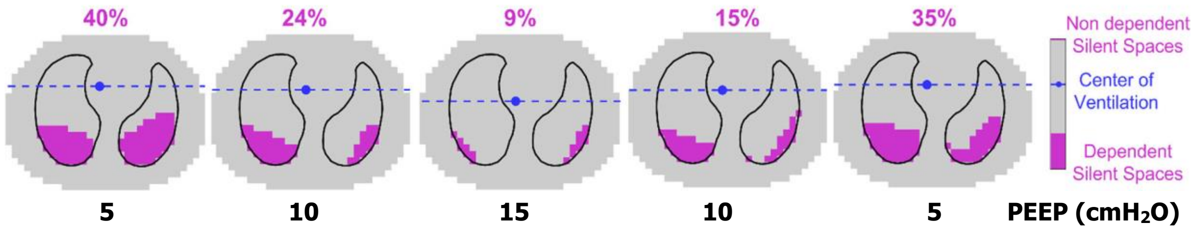

Figure 2: Silent Spaces (violet) and current Center of Ventilation (blue) in a patient examined by SenTec EIT during a stepwise increase and decrease in PEEP (black numbers below the images). The violet numbers above the images show the percentages of areas representing Silent Spaces within the lung regions. During PEEP increase, dependent Silent Spaces decreased and the current Center of Ventilation moved towards dependent regions, implying recruitment in the dorsal lung regions. During PEEP decrease, opposite behavior was observed with an increase in dependent Silent Spaces and a shift of the current Center of Ventilation towards non-dependent regions.

Summary

In summary, SenTec EIT can be used to complement the information derived from the ventilator interface and patient monitoring, and is expected to optimize ventilation settings, reduce ventilator-induced lung injury and shorten the duration of ventilation[4]. Moreover, it can also be used in non-ventilated patients, for example at the onset of first COVID-19 symptoms, allowing better assessment of the initial regional ventilation changes and the need for early interventions.

[2] Kremeier et al. Algorithmenbasiertes Monitoring der Intensivbeatmung mittels elektrischer Impedanztomografie. Pabst Science Publishers 2017.

[3] Spadaro et al. Variation of poorly ventilated lung units (silent spaces) measured by electrical impedance tomography to dynamically assess recruitment. *Crit Care* 22, 26 (2018).

[4] Bachmann et al. Electrical impedance tomography in acute respiratory distress syndrome. *Crit Care* 22, 263 (2018).

Devices implementing SenTec EIT

- BB^2 System (SenTec): The BB^2 System [Link] is the current SenTec EIT stand-alone system that is approved for clinical use in adults and children in Europe and Japan. The BB^2 System is intended for patients, whose underbust girth is within approximately 76 to 128 cm.

- LuMon™ System (SenTec): SenTec expects to gain CE approval for its new LuMon™ System, the successor of the BB^2 System, during the second quarter of 2020. The LuMon™ System is a very compact and lightweight EIT system, which will be available in two configurations:
  - for Adults/Children (intended for patients, whose underbust girth is within approx. 76 to 128 cm)
  - for Neonates/Infants (intended for patients, whose underbust girth is within approx. 17 to 52 cm)

- ELISA 800^{VIT} (Löwenstein Medical): The ELISA 800^{VIT} [Link] is the first intensive care ventilator with integrated SenTec EIT.

- FluxMed (MBMED): The FluxMed [Link] is a Respiratory Mechanics Monitor with an optional EIT module [Link] implementing SenTec EIT.

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