Ventilation therapy involves numerous risks, and could lead to adverse effects. In addition, ventilation condition in the lungs can develop very differently over time in different regions. Traditional imaging procedures only provide a momentary picture of such conditions. Electrical impedance tomography (EIT), in contrast, enables dynamic visualization of the status of the lungs during ventilation. Although EIT has been in use in clinical settings since 2011, a few factors are still missing in order for it to become firmly established. However, the way to a new gold standard in intensive care and anesthesia has been initiated – and the current S3 guidelines on invasive ventilation also list EIT.
Back in the 1980s, it was an impressive result: The first EIT devices delivered one image per second, provided they were used in the proper interference-free electromagnetic surroundings. Today after being part of everyday clinical routine for several years, EIT can provide a far more impressive total of 50 images per second. And external electromagnetic disturbances are much less of a hindrance in obtaining high-quality images of the lungs. EIT visualizes occurrences in the thorax using low-level alternating current in electrodes that rotate around the body. The electrodes are applied to the body surface and operate completely radiation-free.

Changes on the inside of the thorax result in changes in the electrical resistance and this can be determined through small voltage changes on the surface of the skin. To put it in a simplified way, an EIT image is a bioimpedance measurement of the body interior, mainly of the lungs. In contrast to other imaging modalities that work with ionizing radiation, EIT images have a lower spatial resolution but are highly dynamic.  

Measurement of lung ventilation is the main application  
Although EIT was first invented as a medical process in the 1980s, it is still a relatively recent development. It has been used clinically since 2011 when the first EIT device was brought to the market. Up until now, the method has been used mainly for monitoring pulmonary function. Aside from the use of EIT for thoracic imaging, other new application possibilities are also being researched:

- Imaging of gastrointestinal function and evacuation  
- Visualization of certain cerebral functions  
- Early detection of breast cancer²  

In addition to the dynamic imaging that it provides, EIT has other advantages as well: The examination is entirely without radiation and can be conducted at the patient's bedside. It allows for continuous monitoring of regional ventilation and thus a functional visualization of the lungs. Functional variables include:

- Regional compliance  
- Regional lung volume (e.g. tidal volumes)  
- Regional changes in end expiratory lung volume  
- Spatial and temporal ventilation variations¹  

This information can be used to detect signs of pulmonary hyper-distension or the collapse of individual pulmonary regions. No other imaging process provides comparable information directly at the patient’s bedside and without any radiation exposure³.
Improved oxygenation and less tissue damage

Electrical impedance tomography makes it possible to individually set different parameters in ventilation treatment so that equal ventilation distribution is ensured in the ventral and dorsal areas of the lungs. At the same time, this can reduce the stress the lung is exposed to. In the first prospective data on EIT-guided ventilation in connection with pulmonary injuries in an experimental setting, an improvement in gas exchange and respiratory mechanics was found with reduced histological evidence of ventilation-induced parenchymal lesions. Scientists have been quick to recognize the substantial benefits offered by EIT in connection with early detection of regional impairments such as possible injuries pneumothorax or pulmonary edema.

Lung recruitment can be individually adapted and less harmful

It is well known that recruitment maneuvers involve a risk of adverse barotraumatic, volutraumatic and hemodynamic effects. EIT also provides benefits in handling this situation. When considering the countervailing options of restoring adequate oxygenation and protecting lung tissue as much as possible, EIT helps to achieve an exact setting of the necessary parameters. This makes it possible, for example, to adjust PEEP (Positive End Expiratory Pressure) at the patient’s bedside. The precise evaluation of ventilation conditions using EIT thus facilitates personalized lung recruitment.

Individual PEEP adjustment minimizing regional transpulmonary pressures

With the measurement of esophageal pressure, the transpulmonary pressure rather than the absolute pressure can be assessed. As it is the transpulmonary pressure that the lung “sees”, it is the relevant pressure to avoid lung collapse on one hand and to avoid too high pressures and lung hyperdistension on the other. Unfortunately, measuring esophageal pressure is influenced by many variables and does not account for regional differences in transpulmonary pressures brought about by the hydrostatic gradient of the thorax or mediastinal weight. Also, heterogeneities of lung regions with adjacent areas of “solid-like” and “fluid-like” behavior, which are known to act as stress raisers, are not considered and may lead to under- or overestimation of the required PEEP setting. In contrast to this, EIT can be used to visualize changes in regional compliances associated with collapse and hyperdistension at different PEEP levels. The caregiver can now see what happens at different PEEP steps and then chose the least injurious compromise of lung collapse and hyperdistension.
What is lacking for recognition of EIT as a standard?
The biggest obstacle for the recognition of EIT as a standard procedure has been and remains the absence of a definition of essential EIT parameters and their significance for immediate decisions in therapeutic situations. As with ultrasound, there is also a need for a standardized examination procedure. A concrete classification of measurement results and treatment recommendations and diagnoses still needs to be developed before it will be possible to speak of a new gold standard. Further large clinical studies first have to provide a standardized interpretation and presentation of results. The process of becoming part of the clinical routine has been underway some time now. It is increasingly recommended for ventilator management and according to Heines et al. “EIT [...] is a promising tool which has a large potential for becoming the golden standard as a bedside patient-tailored ventilatory setting tool.”

REFERENCE:

11. Roldan R et al., “PEEP Titration In Severe Acute Respiratory Distress Syndrome: Different Physiological Consequences When Guided By Electrical Impedance Tomography Versus Esophageal Pressure”, Am J Respir Crit Care Med, 2017