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EDITORIAL

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EDITORIAL

Focus on Recent Advances in Electrical Impedance Tomography

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This focus collection introduces recent advances in electrical impedance tomography (EIT) in algorithms, hardware developments and clinical applications. It is an exciting time for the EIT community as the number of commercial EIT systems and clinical trials evaluating this technology continues to grow, which is a key drive to enable EIT to become a routine tool of choice. Though EIT is beginning to gain recognition as a useful tool, there are still many challenges left. For example, the EU has funded a major project (CRADL, H2020, 5.5 million Euros; cradlproject.org), focusing on the devastating effects of respiratory failure in infants and children. Each year 15 million babies are born prematurely, and many suffer from respiratory failure due to immaturity of the lung (respiratory distress syndrome (RDS)) and lack of control of breathing. Although respiratory support, especially mechanical ventilation, can improve their survival, it also causes severe injury to the vulnerable lung, resulting in severe and chronic pulmonary morbidity lasting into adulthood. These risks are also present in older infants and children admitted for respiratory failure caused by bronchiolitis and acute respiratory distress syndrome (ARDS). Addressing this problem is essential in order to progress on the millennium development goal (MDG) for child survival by 2015 and beyond. Studies have shown that heterogeneity of lung aeration, resulting in areas of lung over-inflation and lung collapse, plays a crucial part in the risk of mortality and morbidity due to respiratory failure. Avoiding heterogeneity is considered the key to attenuating the detrimental effects of respiratory failure. However, this distribution of lung aeration cannot be detected by currently available bedside monitoring tools and imaging techniques. Therefore, an imaging modality suitable for continuous non-invasive bedside monitoring of infant lung function is urgently needed. Electrical impedance tomography (EIT) is the only technology that is available to address this need.

The challenge was to create a device that is suitable for routine monitoring in intensive care units (ICUs), for which the choices are currently limited mainly because the control software and user interface are designed for experienced operators and off-line analysis, rather than real-time presentation of the key clinical information. Another is the need for CE compliance so it can be used in the clinical environment.

A key problem for EIT is the translation of novel hardware and algorithms into clinically useful tools. Many novel ideas are not translated, and the resulting clinical system achieves merely a subset of the performance promised by the new technologies.

Another key need to EIT's translation is maintaining imaging standards (e.g. DICOM), for EIT image reconstruction algorithms. For clinical applications a number of publications in this area (Adler *et al* 2009, 2012, Hulskamp *et al* 2009, Fawke *et al* 2010) have been produced but more work is needed on this.

This year's focus volume is indicative of recent progress in the modality, which shifts the focus of the developments to new and exciting biomedical applications and clinical studies. Among the collection we note a series of papers on artificial intelligence-inspired approaches in EIT image reconstruction and classification, a trend that resonates with the broader picture of healthcare diagnostics. We mention in particular the works that combine D-bar reconstruction with deep convolutional networks (Hamilton *et al* 2019a) and targeted studies exploring the utility of machine learning tools for bladder state classification (Dunne *et al* 2019) and cardiac monitoring (Murphy *et al* 2019). Although still in their infancy, these approaches have shown promising signs in alleviating some of the effects of the ill-posed inverse problem (Hamilton *et al* 2019b, McDermott *et al* 2019). On the modelling, signal processing and image reconstruction front the contributions of this volume span also to multifrequency EIT (Menden *et al* 2019), filtering biological (heart) noise (Murphy *et al* 2019), compressed sensing in thoracic acquisition (Shiraz *et al* 2019) and joint EIT-EEG inversion (Avery *et al* 2019), sensitivity studies on the effect of nerve dispersion (Tarotin *et al* 2019), and an investigation on the impact of reconstruction settings on physiological parameters (Thürk *et al* 2019). Complementary to these developments was a study on multi-frequency sensing for EIT (Rao *et al* 2019). Thematically the clinical applications are still dominated by brain and chest (ventilation-perfusion monitoring) (Grychtol *et al* 2019) with several focused studies on neuronal depolarisation imaging (Hope *et al* 2019), and neural activity on the peripheral nerve and pulmonary oedema (Hannan *et al* 2019, Stowe *et al* 2019). Overall, the papers report some successes but also challenges in the practical-clinical application of the modality, offering suggestions for further development in improving the robustness of these methods (Frerichs *et al* 2019, Zhao *et al* 2019).

As there are now several commercialised, clinically approved EIT systems for ICU monitoring, hardware specifications tend to be discussed very briefly in research papers, complying with commercial confidentiality and IP restrictions. However, the CRADL project has broken the world record for the most clinical data collected (200 subjects for 72 h at 48 frames a second, approximately 100 terabytes), which should keep researchers occupied for many years to come.

A niche area that still attracts considerable interest is that of breast and prostate cancer screening and imaging where EIT offers some advantages over the ionising modalities. As there is a growing urgency to detect cancer at the early pre-symptomatic stage, the latest developments in EIT and impedance-based hybrid modalities have a critical role to play.

This focus issue of *Physiological Measurement* follows a successful international conference of biomedical applications of EIT held in Edinburgh, in June 2018, attracting an audience of clinicians, engineers, physicists and mathematicians from around the globe.

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