TOPICAL REVIEW

Thoracic electrical impedance tomography in Chinese hospitals: a review of clinical research and daily applications

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Abstract

Chinese scientists and researchers have a long history with electrical impedance tomography (EIT), which can be dated back to the 1980s. No commercial EIT devices for chest imaging were available until the year 2014 when the first device received its approval from the China Food and Drug Administration. Ever since then, clinical research and daily applications have taken place in Chinese hospitals. Up to this date (2019.11) 47 hospitals have been equipped with 50 EIT devices. Twenty-three SCI publications are recorded and a further 21 clinical trials are registered. Thoracic EIT is mainly used in patients before or after surgery, or in intensive care units (ICU). Application fields include the development of strategies for protective lung ventilation (e.g. tidal volume and positive end-expiratory pressure (PEEP) titration, recruitment, choice of ventilation mode and weaning from ventilator), regional lung perfusion monitoring, perioperative monitoring, and potential feedback for rehabilitation. The main challenges for promoting clinical use of EIT are the financial cost and the education of personnel. In this review, the past, present and future of EIT in China are introduced and discussed.

1. Brief introduction of EIT history in China

Electrical impedance tomography (EIT) research in China can be dated back to the 1980s. EIT applications focus mainly on brain and breast imaging in the medical field and on industrial uses of EIT. Researchers from the Fourth Military Medical University and Chongqing University started to study EIT image reconstruction methods and hardware construction in the last century. Results were documented as publications and patents.

Thoracic EIT was rarely studied in China until the breakthrough of the first commercial device receiving its China Food and Drug Administration (CFDA) approval in 2014.04, but has experienced impressive growth since then. In the beginning, several ICUs in major hospitals, especially university hospitals, purchased thoracic EIT devices. Leading opinion leaders in the field were (and still are) conducting clinical EIT trials. With the collected experience and the progress of clinical studies, topics regarding EIT clinical applications have been presented in various domestic scientific conferences. More and more Chinese medical doctors have got to know about this technology and its correlative application fields. Chest imaging dominates current preclinical and clinical EIT research in China, reflecting the general trend that identified thoracic EIT as the most relevant use of EIT in the medical field. In this topical review, we therefore describe the clinical research and daily applications using thoracic EIT in Chinese research institutions and clinical departments.
2. Status of clinical research and daily applications

Up to this date (2019.11) 47 hospitals have been equipped with 50 EIT devices in China (including Taiwan). These are tertiary hospitals at provincial or national levels with bed capacity exceeding 500, located in different regions of China (e.g. Peking Union Medical College Hospital, Beijing, Northern China; Sichuan Provincial People’s Hospital, Western China; The First Affiliated Hospital of Guangzhou Medical University, Southern China; Shanghai Chest Hospital, Eastern China; Far Eastern Memorial Hospital, Taiwan Island). The departments that acquired EIT are mainly Critical Care Medicine and Anaesthesiology departments. The end-users of EIT include intensivists, anaesthesiologists, respiratory therapists, and rehabilitation physicians.

An article search was performed on PubMed (www.ncbi.nlm.nih.gov). The used keywords included ‘electrical impedance tomography’, ‘EIT’, ‘China’, ‘Taiwan’, ‘lung’, ‘thoracic’, ‘pulmonary’, ‘airway’, ‘respiratory’ (individually or in their combinations). Papers published in SCI Journals that were related to EIT technology and carried out by Chinese research teams were reviewed. The research activities focused on thoracic EIT with either animal or human subjects and are summarised in table 1 (only papers with full text in English were listed). After the launch of the first thoracic EIT device in China, the first SCI journal paper was published a year later in 2015 (Long et al 2015). Until November 2019, 20 SCI journal papers were published where Chinese clinical teams were involved and the data were collected in China (including 15 original research papers, three case reports, and two research letters). In addition, three papers were in press and in the phase of proofreading and were also summarised in table 1. Further, the search for new unpublished studies was performed on two clinical trial databases with similar search criteria. In total, 21 clinical trials were found in clinicaltrials.gov (n = 11) or the China Clinical Trials Register Center (www.chictr.org.cn, n = 10), which have not been published in English scientific journals. Their registration numbers and main objectives are described in table 2.

The applications mainly focused on adjusting ventilator settings (e.g. titration of positive end-expiratory pressure (PEEP) and tidal volume; comparing different ventilation modes), evaluation of treatment effectiveness (e.g. the effect of recruitment manoeuvre, suctioning or rehabilitation programme), monitoring patients with spontaneous breathing (e.g. ventilation distribution during support/assist ventilation, spontaneous breathing trial (SBT) and weaning from ventilator), perioperative monitoring and evaluation of surgery, and EIT technique development or validation. In the following, the application fields are discussed in detail and examples of the works from Chinese groups are described.

2.1. Guiding ventilator settings

An adequate PEEP is recommended for patients with acute respiratory distress syndrome (ARDS) to keep the alveoli open and prevent atelectasis (Ferguson et al 2012). Insufficient PEEP cannot maintain alveoli open while inappropriately high PEEP may lead to various lung damages (Brower et al 2004). Individualising PEEP is a common consensus but the superior method is still under debate. EIT-guided PEEP titration is one of the well-accepted applications of thoracic EIT (Frerichs et al 2017). Different individualised EIT titration methods have been proposed. In a study from the Netherlands with 12 post-cardiac surgery patients, these EIT-derived measures did not differ from each other (Blankman et al 2014). However in a recent study with 30 ARDS patients, it was found that in about 10% of the patients the EIT-derived measures exhibited high differences when analysing the same patients (Zhao et al 2019d). The patient groups were different between these two studies (post-surgery vs. ARDS), and some of the titration methods and the sample sizes were different. Since the EIT-derived parameters capture various aspects of lung function and ventilation, it was proposed that the existence of differences in the recommended PEEP among the EIT measures might be a good indicator of functional lung status (Zhao et al 2019d). The authors recommended calculating more than one EIT measure at a time to confirm the selected PEEP level.

Retrospective clinical studies and prospective animal experiments demonstrated the use and superiority of EIT for PEEP titration (Meier et al 2008, Wolf et al 2013, Hochhausen et al 2017). The group from the Far Eastern Memorial Hospital conducted the first prospective outcome study using PEEP titration with EIT in ARDS patients (Zhao et al 2019a). As compared with the retrospective group in which PEEP was titrated with quasi-static pressure–volume (PV) curve (lower inflection point plus 2 cmH2O as selected PEEP), the EIT-based PEEP titration was associated with improved oxygenation, compliance, driving pressure, and weaning success rate (Zhao et al 2019a). In this study, regional respiratory compliance was computed at each PEEP level using the EIT method proposed previously (Costa et al 2009). The PEEP levels (PEEP_{max,C}) of individual maximum regional compliance were identified during decremental PEEP trials (figure 1). At PEEP levels higher than PEEP_{max,C}, overdistension percentages were estimated. At PEEP levels lower than PEEP_{max,C}, the collapse percentages were calculated. The optimal PEEP level selected for the patients was the intercept point of cumulated collapse and overdistension percentage curves, which is postulated to provide the best compromise between collapsed and overdistended lung. If the intercept point occurred between two
| Publication year | Subjects | Study type | Main finding of EIT |
|------------------|----------|------------|--------------------|
| 2015 (Long et al 2015) | 18 ARDS patients | Observational | PEEP titration significantly affected regional gas distribution in the lungs, which could be monitored with EIT |
| 2016 (Liu et al 2016) | ARDS model in 10 pigs | Experimental | Method developed and evaluated to identify regional overdistension, recruitment and cyclic alveolar collapse |
| 2016 (Hsu et al 2016) | 19 ARDS patients | Observational | EIT was able to identify slow recruitment associated with late improvements in oxygenation following PEEP change |
| 2016 (He et al 2016) | 50 OP patients | Randomised-control | EIT-guided PEEP titration led to a better oxygenation and ventilation distribution in patients undergoing laparoscopic abdominal surgery |
| 2016 (Yun et al 2016) | 20 ARDS patients | Observational | The discrepancy between lung tissue reopening and oxygenation improvement after recruitment manoeuvre was identified with EIT |
| 2017 (Hsu et al 2017) | 16 patients with PMV | Observational | Ventilation redistribution and ventilation delay based on EIT can help to identify respiratory muscles reactivation |
| 2017 (Sun et al 2017a) | 15 AECOPD patients | Crossover | EIT could be used to identify better support ventilation mode in regard to ventilation distribution |
| 2017 (Sun et al 2018) | 1 ARDS patient | Case | Regional airway closure could be confirmed with EIT |
| 2017 (Zhao et al 2017) | 30 patients during SBT | Observational | Regional ventilation distribution patterns during inspiration were associated with weaning outcomes, and may be used to predict the success of extubation |
| 2018 (Zhao et al 2018b) | 3 ICU and 1 OP patients | Cases | Various methods of functional EIT imaging were compared under clinical settings |
| 2018 (Zhang et al 2018) | 41 healthy and 67 obstructive | Observational | EIT could be used to evaluate the degree of obstruction in patients with obstructive ventilatory defects on the global and regional levels |
| 2018 (Zhao et al 2018b) | 24 patients with OLV | Observational | It is feasible to titrate tidal volume and PEEP at the bedside during OLV using EIT in combination with PaO2 |
| 2018 (Gong et al 2018) | 1 ARDS patient | Case | EIT reconstruction method improvement |
| 2018 (Wang et al 2018) | 9 patients with OLV | Observational | EIT can monitor ventilation during minimally invasive thoracic surgery without intrusion in the surgical field |
| 2018 (Zhao et al 2018a) | 1 MMA patient | Case | The use of EIT to select a suitable method for inspiratory muscle training was possible and useful |
| 2018 (Su et al 2018) | 23 ARDS patients | Observational | PEEP titration with EIT was explored |
| 2019 (Zhao et al 2019a) | 55 ARDS patients | Current vs. historical cohorts | As compared with pressure-volume curve, the EIT-guided PEEP titration may be associated with improved oxygenation, respiratory compliance, driving pressure, and weaning success rate |
| 2019 (Zhao et al 2019b) | 1 PMV patient | Case | Patient immediate responses to IMT can be measured with EIT. Individual IMT strategies can be developed |
| 2019 (Zhao et al 2019c) | 14 ARDS patients | Observational | Two previously proposed EIT-based methods were not able to assess pulmonary oedema in the clinical settings |
| 2019 (Zhao et al 2019d) | 30 ARDS patients | Observational | Differences exist in the recommended EIT among various EIT measures, which might be an indicator of non-recruitable lungs and heterogeneous airway resistances |
| 2019 (Liu et al 2019) | 100 surgical patients over 65 years old | Randomised-control | PEEP setting with EIT effectively improved oxygenation and lung mechanics during one-lung ventilation compared to a fixed PEEP of 5 cmH2O in elderly patients undergoing thoracoscopic surgery |
| 2019 (Zhao et al 2020) | 18 COPD and 7 asthma patients | Observational | Asssaying regional air trapping by calculating the regional end-expiratory flow, which could provide diagnostic information for monitoring the disease progression during treatment |
PEEP levels, the selected PEEP corresponded to the PEEP step toward the lowest global inhomogeneity index, which indicated the degree of homogeneity of ventilation distribution (Zhao et al 2009). The same group had just completed a prospective randomised study comparing the same EIT-based PEEP with maximal hysteresis of the quasi-static PV curve in moderate-to-severe ARDS patients. Preliminary results for 87 randomised patients were presented at the annual EIT conference in 2019 (Hsu et al 2019), suggesting a better survival rate in the EIT group.

Individual PEEP titration may be needed not only for ARDS patients in the ICU but also for patients under surgery. The current practice is that a fixed PEEP of 5 cmH₂O or no PEEP is applied in surgery patients without lung diseases. Liu et al have conducted a prospective randomised study comparing

### Table 1. (Continued)

| Publication year | Subjects | Study type | Main finding of EIT |
|------------------|----------|------------|---------------------|
| 2020 (Yuan et al 2020) | 18 post-OP patients | Crossover | The change of EELI measured by EIT showed the effects of therapy and body position changes |

AECOPD, acute exacerbation of chronic obstructive pulmonary disease; ARDS, acute respiratory distress syndrome; COPD, chronic obstructive pulmonary disease; EELI, end-expiratory lung impedance; IMT, inspiratory muscle training; MMA, methylmalonic acidemia; OLV, one-lung ventilation; PaO₂, arterial partial pressure of O₂; PEEP, positive end-expiratory pressure; PMV, prolonged mechanical ventilation; SBT, spontaneous breathing trial.

### Table 2. Registered clinical trials that have not been published yet.

| Planned study completion year | Registration number | Investigator | Study type | Main objective |
|-------------------------------|---------------------|--------------|------------|----------------|
| 2015                          | NCT02292992         | Lee Chao-Hsien | Crossover  | The difference of EELI detected by EIT between nasal pillow mask and HFNC after extubation |
| 2019                          | NCT02361398         | Yun Long      | Randomised | PEEP titration with EIT vs. best oxygenation |
| 2018                          | NCT03112512         | Chang Mei Yun | Randomised | PEEP titration with EIT vs. maximal hysteresis |
| 2018                          | NCT03118804         | Liu Songqiao  | Observation | Weaning from ventilator guided by EIT |
| 2018                          | NCT03244761         | Jian-Xin Zhou | Crossover  | Comparing standard and modified T-HFO in change of PEEP and EELI |
| 2019                          | NCT03498807         | Hou T Chang   | Randomised | PEEP titration with EIT vs. PV loop |
| 2019                          | NCT03738345         | Jie Li        | Observation | Different flow settings of HFNC for healthy and hypoxemia subjects |
| 2020                          | NCT03763890         | Haibo Qiu     | Crossover  | Evaluating the impact of PEEP on alveolar heterogeneity |
| 2019                          | NCT03830099         | Jian-Xin Zhou | Observation | Evaluating ventilation distribution in patients after neurosurgery |
| 2019                          | NCT04081142         | Yun Long      | Observation | Regional perfusion measurement with EIT plus saline for ICU patients |
| 2019                          | NCT04081155         | Yun Long      | Observation | Evaluating the effect of PEEP on regional ventilation and perfusion |
| 2018                          | ChiCTR-ROC-17011321 | Wang Yuguang  | Observation | EIT-guided body position selection on clinical outcomes |
| 2019                          | ChiCTR1800015680    | Weng Yibing   | Case-control | Weaning strategy development with EIT |
| 2020                          | ChiCTR1800016754    | Hai-rui Liu   | Randomised | EIT-guided PEEP titration vs. fixed PEEP in patients under intracranial tumor surgery |
| 2019                          | ChiCTR1800019359    | Meiyiing Xu   | Randomised | EIT-guided PEEP titration vs. fixed PEEP in elderly under lung resection |
| 2019                          | ChiCTR1900021119    | Jingxiang Wu  | Randomised | EIT-guided PEEP titration vs. fixed PEEP in elderly under thoracoscopic surgery |
| 2019                          | ChiCTR1900021649    | Hairui Liu    | Randomised | Comparing two RM on ventilation distribution and clinical outcomes |
| 2020                          | ChiCTR1900023897    | Tianzuo Li    | Randomised | EIT-guided ventilator settings in prolonged general anaesthesia during abdominal surgery |
| 2019                          | ChiCTR1900025184    | Huisheng Xu   | Observation | Ventilation distribution during ESD of upper gastrointestinal mucosa |
| 2020                          | ChiCTR1900025656    | Chen Xiaoping  | Randomised | Effect of EIT-guided PEEP on right ventricular function |

ESD, endoscopic submucosal dissection; HFNC, high flow nasal cannula; RM, recruitment manoeuvre; T-HFO, high-flow oxygen therapy applied to the tracheostomy cannula.
outcomes of EIT-guided PEEP and a fixed PEEP of 5 cmH₂O in 100 elderly patients undergoing thoracoscopic surgery. The results indicated that individual PEEP settings might improve lung mechanics and oxygenation, but not other outcomes such as lung complications and duration of hospitalisation (Liu et al 2019). Besides the use of PEEP, small tidal volume is recommended for ARDS during mechanical ventilation (Ferguson et al 2012). However, no guideline is given for surgery patients (e.g. for cardiac surgery patients during one-lung ventilation; figure 2). The same research group examined different tidal volumes in nine patients (Wang et al 2018), and examined the combination of various PEEP levels in 24 patients under thoracic surgical procedures (Zhao et al 2018b). The ventilation distribution and the corresponding oxygenation differed significantly among various tidal volume and PEEP steps. One of the findings of these studies was that it was feasible to titrate tidal volume at the bedside by using EIT in combination with PaO₂.

2.2. Evaluation of treatment effectiveness
It is known that not all regions within the lungs are recruitable in patients with ARDS (Gattinoni et al 2006). We might ‘guess’ whether the lungs are recruitable by considering the oxygenation after the recruitment manoeuvre. However, if the oxygenation is not improved, does it necessarily mean the lungs were not recruited? Should higher recruitment pressure be applied? To answer these questions, Long and his colleagues conducted a study on 20 ARDS patients undergoing a recruitment manoeuvre (Yun et al 2016). It was found that even when remarkable lung tissue reopening was detected (confirmed via EIT), the oxygenation did not necessarily increase. The authors suspected that lung ventilation/perfusion mismatch could be significant in such patients. Therefore, a workflow evaluating the effect of recruitment manoeuvre was proposed, which required bedside monitoring of ventilation distribution and oxygenation (figure 3).

To evaluate lung perfusion, on the other hand, one may use mathematical methods to analyse the cardiac-related signal in the EIT data. However, the accuracy was shown not to be as high as with the method based on hypertonic saline bolus injection (Borges et al 2012). Up to now, no studies have been published on human subjects using EIT with saline bolus injection. Again, Long and his group from the Peking Union Medical College Hospital are conducting a study on lung perfusion detection using EIT and saline bolus injection on various patients (NCT04081142). Preliminary results indicated that with 10 ml 10% saline bolus during end-inspiration or end-expiration hold, lung perfusion could be detected with EIT. No side effects were observed so far. Diagnosis and evaluation of treatment efficacy could be demonstrated in patients with acute pulmonary embolism.

2.3. Monitoring patients with spontaneous breathing
One of the treatment objectives for patients under mechanical ventilation is to resume spontaneous breathing and reduce ventilation support as soon as possible, to minimise the risk of ventilator-associated pneumonia, airway trauma, atrophy and diaphragm dysfunction (Petrof and Hussain 2016). However, spontaneous breathing effort during mechanical ventilation may cause pendelluft, which results in lung damage (Yoshida et al 2013). Therefore, it is important to monitor patients with spontaneous breathing to
Figure 2. Tidal ventilation distribution in a patient measured with EIT during ventilation of two lungs (TLV) and one lung (OLV). Highly ventilated regions are coded in light blue. Pixel values are relative impedances in arbitrary units. All sub-figures have the same colour scale. The tidal volume and breathing rate are indicated above each image.

Figure 3. Illustration of the workflow evaluating the effect of a recruitment manoeuvre by means of EIT and oxygenation, based on the information given in the publication (Yun et al 2016).

identify potential risks. Sun et al compared neurally-adjusted ventilator-assist (NAVA) with pressure support ventilation in 15 COPD patients and found that NAVA increased ventilation distribution in the most dependent regions and reduced dead space (2017a). However, to capture the pendelluft during spontaneous breathing, which usually happens during the beginning of inspiration, intratidal gas distribution should be
Figure 4. Customised software to evaluate weaning outcome at the bedside. The spontaneous breathing trial is divided into two parts. The first part is with higher support level (lower patient load); the second half is with lower support level (higher patient load). At the end of each period, EIT data are recorded and analysed by the software. The weaning pattern is automatically identified. For the definition and identification of the weaning pattern types please refer to Zhao et al (2017). ACMV, assist-control mechanical ventilation mode.

calculated (Lowhagen et al 2010). Zhao et al analysed 30 patients under prolonged mechanical ventilation. Four different intratidal gas distribution patterns were found, corresponding to different weaning success rates (Zhao et al 2017). Following this study, customised software was developed which is now available to end-users to further evaluate whether the method can be used to guide spontaneous breathing trial and to predict weaning outcome (figure 4).

2.4. Perioperative monitoring and evaluation of surgery, and EIT technique development or validation

Anaesthesiologists are interested in ventilation distribution during various types of surgery. Before the era of EIT, no bedside tool could achieve this task. At the moment, several studies are being conducted in this field. For example, the group from the People’s Hospital of Quzhou is interested in ventilation distribution during endoscopic submucosal dissection of upper gastrointestinal mucosa (ChiCTR1900025184). The measurement time points during surgery are important, since monopolar or bipolar surgical diathermy may create strong interference to EIT measurement. In the extreme case, EIT hardware could be damaged. Harmonic scalpel use would not influence EIT measurement but it is not widely used compared to diathermy. In another study, the authors have compared post-operative ventilation distribution in cardiac surgical patients after traditional full sternotomy or minimally invasive thoracotomy in 40 patients. While the data are still being analysed, preliminary results show large variations in regional ventilation recovery. The findings indicated that EIT might identify inter-individual differences in postoperative lung function recovery among the patients, enabling personalised therapy and care of patients after extubation.

EIT was also proposed to detect pulmonary oedema (Kunst et al 1999, Trepte et al 2016). The validation of this approach was carried out in a clinical setting on 14 ARDS patients (Zhao et al 2019c). Unfortunately, simple left-to-right and anterior-to-posterior ventilation ratios derived from EIT examinations after postural changes did not reflect total extravascular lung water in the study population. Further advanced measures have to be developed and evaluated to assess the level of pulmonary oedema. In another study, several commonly-used functional EIT (fEIT) images, quantifying tidal ventilation distribution, were evaluated in a clinical setting. The pros and cons of those functional EITs were discussed (Zhao et al 2018c). A more thorough and deeper understanding of the examined approaches to fEIT image generation was provided. It was confirmed that fEIT based on standard deviation calculation is subject to baseline drift and influenced by signals other than respiration. Therefore, it is rarely used in clinical practice. However, in the case of pendelluft, the phase differences in respiratory signals of various regions cannot be captured by other common fEIT images (i.e. using tidal variation and regression) and the ventilation in certain regions might be underestimated (figure 5).
3. The challenges of chest EIT in China

Chest EIT provides unique information that no other established techniques can substitute. Before the EIT era, physicians assessed lung function at the bedside, based on global lung mechanics, hemodynamics, blood gas analysis, ultrasound and x-ray images. With EIT, different measures of lung function can be determined on a regional level and their distribution within the chest can be visualized. Thus, in contrast to the other mentioned methods, only EIT reveals the exact spatial distribution of regional lung function. Although the acceptance of chest EIT in hospitals is increasing after 5 years of promotion, there are challenges identified in clinical practice. The challenges we are facing in China at the moment include acquisition and maintenance costs of EIT devices, end-user motivation and workload, and consensus and guidelines for particular applications.

3.1. Acquisition and maintenance costs of EIT devices

EIT data acquisition and device maintenance cost money. Because EIT is only a monitoring tool, not a diagnosis or life-support tool, its necessity relative to investment is often under debate. At this moment, only two hospitals in Taiwan have managed to pass the local regulations and charge patients for their usage of EIT. Many hospitals have expressed their interest in equipping their departments with EIT devices but the reimbursement of the device and measurement costs is their biggest concern. We can imagine, once this issue is solved countrywide, that the number of Chinese hospitals equipped with EIT devices would rapidly increase within a short period.

3.2. End-user motivations and workload

As mentioned at the beginning of the paper, the typical end-users are intensivists, anaesthesiologists, respiratory therapists and rehabilitation physicians. However, these healthcare professionals might potentially have conflicts of interest about other personnel taking care of the patients. In an operation theatre scenario, when an anaesthesiologist wants to add EIT to the routine, this would introduce issues such as additional preparation time or potentially limiting the operation field. Under such circumstances, surgeons might oppose the extra measurement. In an ICU scenario, respiratory therapists are only available in a few ICUs. In most of the ICUs intensivists need to adjust ventilator settings among many other activities. They might be reluctant to add an additional measurement to their routine. ICU nurses could also complain about...
the EIT measurement procedure, which might be performed during their work on patients. We have met these issues in the early promotion of EIT in the hospital. We consider these to be influenced by a lack of education on EIT technology, which can be eliminated: an embedded EIT educational program in traditional education could be helpful in the long term.

3.3. Consensus and guidelines for particular applications
A consensus paper on chest EIT was recently published (Frerichs et al 2017). However, due to a lack of prospective randomised studies at the time of writing that document, specific guidelines for particular applications of exact procedures could not be provided. To use EIT in daily clinical routine, clear guidelines are required on how EIT should be used for predefined applications and how the information should be interpreted. We have summarised terminology and various data analysis methods in the consensus paper (Frerichs et al 2017) but an automatic interpretation of the results and ready-to-use software are still warranted. With more upcoming prospective randomised studies, we will be more confident to formulate our guidelines on the daily use of EIT in the future.

3.4. Technical limitations in present EIT systems (hardware and software)
Currently, only one EIT system is available commercially in China, which is PulmoVista 500 from Dräger Medical, Lübeck, Germany. Another major vendor of EIT technology, Timpel, São Paulo, Brazil with the Enlight 1800, plans to introduce the device to the Chinese market in 2021. No further information from other vendors was available at the moment of this review. As of February 2020, no original papers using those devices in Chinese hospitals have been published.

PulmoVista 500 is equipped with electrode belts designed for use in lying patients in intensive care units and operation theatres. Applications for subjects in the sitting position or for women with large breasts are not ideal due to possible bad electrode contact. Certain electrodes with insufficient skin contact would need to be pressed (manually or by leaning on a back rest) or fixed with duct tape. Electrode movement introduces baseline shifts, which could be an issue for long-term monitoring. Besides, ICU patients already have many cables connected to various monitoring devices and the EIT cable may add an extra burden. Wireless electrodes with local analog-to-digital converters could be a solution.

Current online software displays impedance trend, ventilation distribution in different regions of interest, and several indices for PEEP titration. As the clinical application scenarios of EIT dramatically increase, many analyses have to be done offline with customized software for particular applications. Further development of online software should be scenario-based.

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Conflict of interest
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