Electrical Impedance Tomography: Computation and Applications

Part 2: Main Applications of EIT

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Jyväskylä Summer School 2026

August 2026

Why Applications Matter

EIT is mathematically fascinating, but its main appeal comes from a simple promise:

Fast, low-cost, noninvasive imaging of conductivity changes

In this section, we will see how this idea appears in:

- bedside lung monitoring,
- emerging medical applications,
- geophysical surveys,
- industrial and object imaging.

The recurring theme: EIT is often strongest as a monitoring tool, not as a high-resolution anatomical imaging method.

Thoracic EIT: The Flagship Medical Application

The lungs are an especially favorable target for EIT:

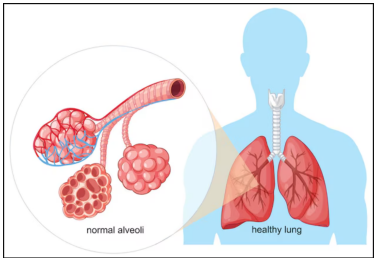
- The lungs are large, making limited spatial resolution less problematic.
- Air is highly resistive, so inflation produces large, repeatable impedance changes.
- EIT tracks regional ventilation in real time.
- For ventilated patients, EIT provides continuous bedside feedback without ionizing radiation.

Image adapted from the Dräger PulmoVista 500 webpage

What Does Thoracic EIT Show?

Key vocabulary:

- **Alveoli:** Tiny air sacs where oxygen and carbon dioxide are exchanged with the blood.
- **Aeration:** The amount of air in a lung region at a given time.
- **Ventilation:** Movement of air into and out of a lung region.
- **Collapse:** Loss of aeration as alveoli close or fail to remain open.
- **Overdistension:** Excessive expansion of open lung regions.



EIT shows **regional** ventilation and aeration changes, from which clinicians estimate collapse and overdistension.

Treating ARDS: Why Regional Information Matters

- **Acute respiratory distress syndrome (ARDS)** is a life-threatening lung injury causing fluid buildup and alveolar collapse. It often requires mechanical ventilation.
- ARDS is spatially heterogeneous: regions may be collapsed, adequately aerated, or overdistended.
- A ventilator setting that reopens one region may overstress another.
- Global measurements may look acceptable while harmful regional collapse or overdistension persists.

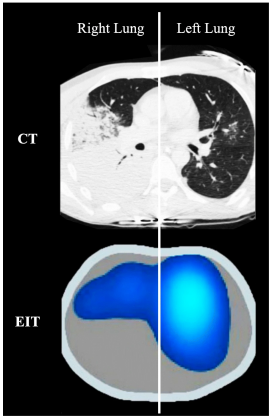
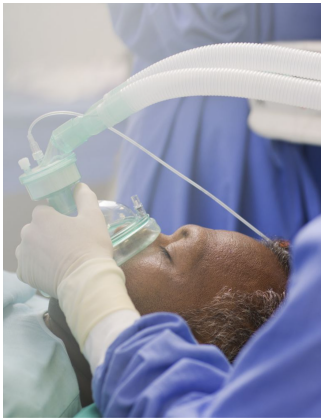


Image: Bachmann et al., 2018

Application Spotlight: EIT-Guided PEEP

- **Positive end-expiratory pressure (PEEP)** maintains airway pressure at the end of expiration to help prevent alveolar collapse.
- A **PEEP trial** tests several pressure levels. Increasing PEEP may reopen collapsed regions, but can overdistend regions that are already open.
- EIT estimates this regional balance, helping clinicians individualize PEEP.



Sources: Bachmann et al. 2018; Songsangvorn et al. 2024; Francovich et al. 2025; Frerichs et al. 2026.

Other Thoracic Applications

Application	What EIT shows
Ventilation monitoring	Regional ventilation, breath by breath.
Guiding treatment	Responses to positioning and ventilator changes.
Ventilation–perfusion assessment	Regional matching of airflow and blood flow.
Detecting acute problems	Sudden ventilation loss from pneumothorax or a misplaced breathing tube.
Pediatric and chronic lung disease	Regional lung function in CF and other chronic conditions.

Sources: Frerichs et al. 2026; He et al. 2025; Sang et al. 2020; Qu et al. 2025.

Thoracic EIT in Clinical Practice

Current status

- Commercial bedside EIT systems are available.
- EIT is used clinically and in research at selected ICUs and perioperative centers.
- Adoption varies by country and institution.

Barriers to wider adoption:

- Artifacts and sensitivity to belt placement.
- Need for standardized acquisition and interpretation.
- Training and workflow demands.
- Limited high-quality evidence for patient-centered outcomes.

Bottom line: Thoracic EIT is clinically available and increasingly used, but is not yet a universal standard of care.

Sources: Scaramuzzo et al. 2024; He et al. 2025; Yuan et al. 2025; Frerichs et al. 2026.

Medical EIT Beyond the Lungs

Many other medical applications of EIT have been explored:

- Stroke detection and classification
- Bladder volume monitoring
- Cardiac/perfusion monitoring
- Cancer detection
- Muscle function

Let's highlight stroke EIT ...

Stroke Triage: Why the Type Matters

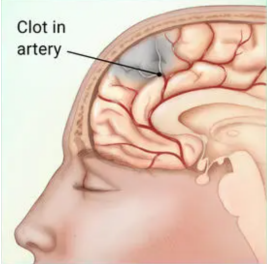
Stroke damages brain tissue through blocked blood flow or bleeding.

Ischemic stroke

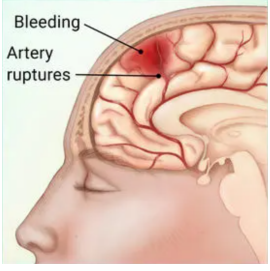
- A clot blocks blood flow
- Treatment aims to restore blood flow

Hemorrhagic stroke

- A blood vessel ruptures or leaks
- Treatment aims to control bleeding



Symptoms may look similar, but clot-busting drugs used for ischemic stroke can be dangerous in hemorrhagic stroke.



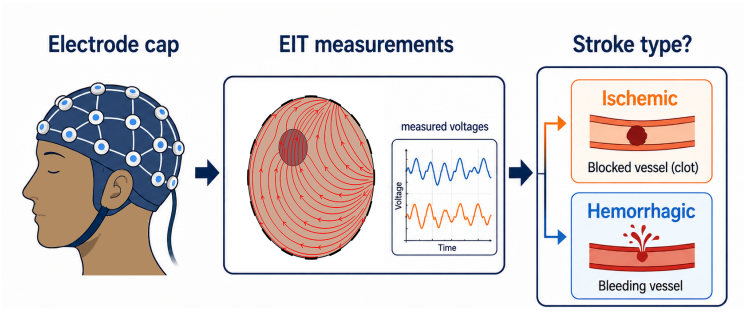
Why Portable Stroke Imaging Could Help

- Brain injury progresses quickly, so rapid treatment is essential.
- Most patients must reach a hospital for brain imaging (often CT) before stroke-specific treatment.
- Could portable EIT identify the stroke type sooner?

EIT and Stroke Classification

The idea is simple:

- Place electrodes around the head.
- Collect EIT data.
- Distinguish ischemic from hemorrhagic stroke.



The goal is classification, not a detailed image of the brain.

Stroke EIT: Main Challenges

- The resistive skull weakens and distorts the signal.
- Small or deep strokes produce subtle changes, while EIT has low spatial resolution.
- Patient anatomy, electrode placement, and contact quality vary.
- Studies remain relatively small; large-scale clinical validation is needed.

Current status: actively studied, but not yet a routine clinical tool.

Beyond Medical EIT

The same basic idea applies outside medicine:

- inject electrical currents,
- measure boundary voltages,
- infer the internal conductivity or resistivity distribution.

Terminology

- In geophysics, this is usually called **electrical resistivity tomography (ERT)** or **electrical resistivity imaging (ERI)**.
- In industry, it is often called **electrical resistance tomography (ERT)**.

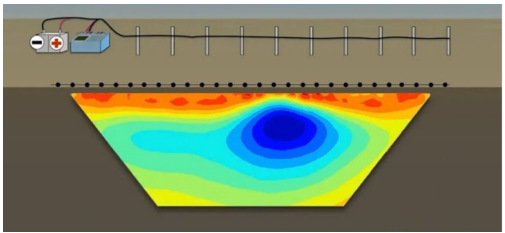
Geophysical ERT/ERI Applications

Application	**What ERT helps investigate**
Groundwater	Aquifers, water movement, infiltration, and saltwater intrusion.
Contamination and cleanup	Contaminant plumes, landfill leachate, and cleanup progress.
Ground stability and infrastructure	Landslides, seepage, voids, and weak or wet zones.
Resources and environmental change	Minerals, geothermal systems, permafrost thaw, and underground CO_2 storage.

Sources: Dimech et al. 2022; Lapenna et al. 2022; Herring et al. 2023.

Geophysical ERT/ERI: How Is Data Collected?

- Metal electrode spikes are inserted along a line or grid.
- Current is injected through selected electrodes; voltage differences are measured on others.
- The data are used to reconstruct subsurface resistivity.



Images: (left) Critex website, (right) Earthscope Consortium Science YouTube Channel

The result is typically a 2D cross-section or 3D subsurface model.

Time-Lapse ERT

Key idea: compare resistivity images over time.

- A baseline survey is collected before a change occurs.
- Later surveys are collected after rainfall, pumping, tracer injection, or remediation.
- The reconstruction highlights where the subsurface electrical properties changed.

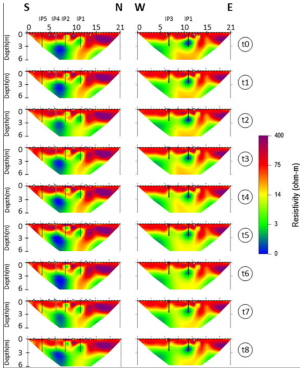


Image: Trento et al., 2021

Why this is powerful

For many geophysical applications, changes over time are easier to interpret and more useful than a single absolute resistivity image.

Geophysical ERT in Practice

Current status:

- Commercial systems support 2D, 3D, and time-lapse surveys.
- ERT is routinely used in environmental, engineering, groundwater, and mineral investigations.

Important limitations:

- Resistivity is affected by water content, salinity, clay, minerals, temperature, and pore structure.
- Electrode contact, terrain, buried metal, and electrical noise can affect the data.
- Images require site-specific interpretation and are often combined with boreholes, samples, or other geophysical measurements.

Bottom line: Geophysical ERT is well established, but resistivity patterns do not uniquely identify underground materials.

Industrial and Other EIT/ERT Applications

Application	What ERT shows
Multiphase flow	Distribution of gas, liquid, and solid phases in pipes and vessels.
Process monitoring	Mixing, settling, filtration, crystallization, and drying.
Trees and wood	Moisture, cavities, decay, and other internal defects.
Structural health	Damage in conductive or self-sensing materials.

Sources: Primrose 2008; Tapp et al. 2003; Martin et al. 2021; Tallman et al. 2023.

Spotlight: Multiphase Flow Monitoring

- Many processes mix gas, liquid, and/or solids (for example, bubbles in liquid, oil and water, or suspended particles).
- Their contrasting electrical properties allow ERT to estimate their distribution across a pipe or vessel.
- Images reveal uneven flow, trapped gas, settling, poor mixing, or stagnant regions.
- This supports process design, troubleshooting, and real-time monitoring.

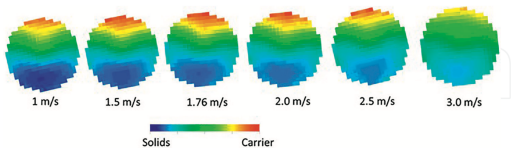


Image: Graham et al., 2018

Like thoracic EIT, this uses fast imaging to track rapid changes.

Takeaways: Where EIT/ERT Is Useful

Across applications, EIT/ERT is strongest when:

- the target produces a meaningful conductivity or resistivity contrast,
- changes over time are more important than fine spatial detail,
- continuous, portable, or noninvasive monitoring is valuable,
- the images can be interpreted together with other information.

Bottom line: EIT/ERT does not replace CT, MRI, drilling, sampling, or ultrasound... but it can complement them with fast, repeated, low-cost measurements.