



Mini-Manual

Electrical Impedance Tomography (EIT)

Device handling, application tips and examples

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This manual is intended to provide additional guidance for the use of PulmoVista® 500. The information and data provided in this manual are subject to technical changes. For the use of the Dräger products, the instructions for use enclosed with the products always apply and are not in any way replaced or otherwise superseded by this manual.

Medical knowledge is subject to constant change due to research and clinical experience. The authors of this publication have taken utmost care to ensure that all information provided, in particular concerning applications and effects, is current at the time of publication. This does not, however, absolve readers of the obligation to take clinical measures on their own responsibility.

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Introduction

Welcome to the world of Electrical Impedance Tomography (EIT).

PulmoVista® 500 is the first clinical EIT device which up to date has been used in several thousand patients. EIT is a non-invasive imaging technique that gives you a special view inside the lungs. In a cross-sectional projection, the distribution of the tidal volume in the thorax is shown. This illustration shows ventilated and non-ventilated areas of the lungs as well as their changes as a function of time. The device can be used in various situations in everyday clinical practice. You have the ability to examine at the bedside the status of your patients' lung, track and assess therapeutic measures in real time.

This manual is intended to assist you in the use of this device and to provide tips and special features in order to implement the presented information in a practical way.

PulmoVista® 500



1. Prepare the device for the clinical use

1.1. START AND DEVICE CHECK

Press the green power button in the lower left corner of the screen to turn on the device. The device check ensures that all components of the device and the trunk cable (cable from the device to the patient) function properly.



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1. Make sure the device is in standby mode (Start/Standby).
2. Plug-in the trunk cable into the trunk cable port and insert the patient cable plugs into their respective test connectors → match label and color.



D-2280-2010 | D-2281-2010



D-11961-2017



D-11960-2017



3. Select ›Device Check‹.
4. Select ›Start‹ and confirm with the *Rotary Knob*.
5. The device check is running automatically. Wait for the test phase to finish.
The device will announce the test result.



If the device check fails, check the message and, if necessary, the connectors. If the problem persists, stop using the device and contact customer service.

1.2. SELECTION AND APPLICATION OF THE ELECTRODE BELT

1.2.1. Choose the right belt size

The application requires an EIT patient interface. This consists of an elastic electrode belt (16 electrodes) and an attachable patient cable. In order to cover a wide patient spectrum, there are five belt sizes, from 70 cm to 150 cm chest circumference. Electrode belt and patient cable are marked in size and color. Both the electrode belt and the patient cable are reusable and can be disinfected with wipes.

Size table

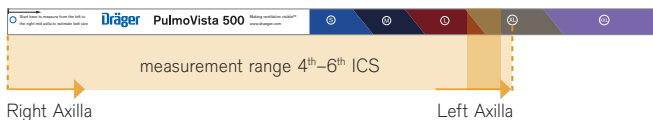
		Size in cm	Size in inch
	XXL	124 – 150	49 – 59
	XL	106 – 127	42 – 50
	L	92 – 110	36 – 43
	M	80 – 96	31 – 38
	S	70 – 85	28 – 33



How to find the right belt size

a. Determine the proper belt size with the help of the measurement tape

- Measure about 5 cm (two inches) below the armpit from axilla to axilla (4th to 6th ICS).
- If the area is in the transition zone between two sizes, the next larger belt is recommended.

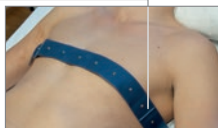


b. Determine the size with the electrode belt

- Choose the electrode belt which you think might possibly fit
- The electrode belt has a *mid position marker* 1. Hold it approx. 5 cm below the right or left axilla and place the end with the belt closure 2 over the thorax to the opposite side.
- The belt should fit when the closure holes, preferably the one in the middle, are below the opposite axilla.
- Otherwise, choose the next smaller or larger belt.

1 Mid position marker

2 Closure holes



Applying an EIT electrode belt to estimate the right fit.
This EIT electrode belt has the correct size.

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D-11923-2017

D-11922-2017



Electrode belt too short

D-11925-2017



Electrode belt too long

1.2.2. Attach patient cable to electrode belt

Take the electrode belt and the corresponding patient cable and attach the patient cable to the electrodes in a zigzag pattern. Attach snap 1 of the patient cable to stud 1 of the electrode belt.

Pay attention to the correct orientation of the patient cable. At the electrodes 1 and 16 there are lines that serve as a guide. Ensure the orientation of the cable over the stud is maintained as illustrated and as marked on the electrode belt.

Orientation of the patient cable and electrode belt



»wrong«

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»correct«

When attaching the electrode cable avoid too tight bending radii, especially at the transition points between electrodes 4/5 and 12/13 (port left/right).



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1.2.3. Prepare the patient

Before the electrode belt is put on, check the potential necessary preparations to position it well. For example, wound dressings, drainages, ECG electrodes, catheters, strong hair growth or surgical and disease-related problem areas may impair the placement of the belt or electrodes. If possible, the contact area should be exposed to improve skin contact. However, if one electrode has insufficient skin contact, the EIT measurement can also be started in the so-called 15-electrode mode. Further information can be found in the chapter ›Checking signal quality‹.

1.2.4. Prepare the electrode belt

To be ready for use as quickly as possible, it is advisable to moisten the electrodes of the electrode belt with a small amount of liquid (e.g. sterile saline solution, water or electrode gel), in particular with dry skin.

1.2.5. Positioning of the electrode belt on the thorax

For orientation and easier alignment there is a noticeable silicone marking on the electrode belt. This *mid position marker* is located between the 8th and 9th electrode and should be positioned on the spine between the 4th and 6th ICS.

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Mid position marker

1.2.6. General procedure when attaching the electrode belt

Apply the belt to the supine patient by

- lifting the patient's upper body or
- rolling the patient to the side.

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45° to 80°



If the patient condition allows it, it may also be advisable to bring the bed in an elevated position. This makes it easier to put on the belt. The EIT measurement can be performed regardless of the position, e.g. in seated, supine, prone or lateral position.

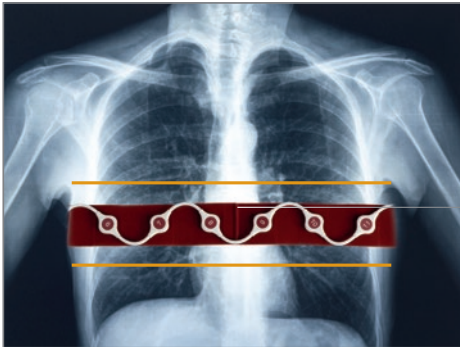
If tilting the bed or an upright patient position is not possible, the following methods for applying the electrode belt are available:

Lifting method

1. Lift the patient's head and put the *mid position marker* of the belt to the cervical spine.
2. Lift the upper body a bit to move the belt downwards to place it between the 4th and 6th intercostal space.
3. Ensure that the *mid position marker* is still on the spine.
4. Close the belt



If access from the head is restricted, lift the upper body and put on the electrode belt from the side.



Mid position marker

4th to 6th ICS

Rolling method

1. Turn the patient on one side, place one half of the belt around the chest (electrode on the left side of the patient) and hold the *mid position marker* on the spine in the area of the 4th to 6th ICS.



Mid position marker

2. Turn the patient over to the other side while holding the marker. Gently push the free end of the belt under the patient and place it on the chest.
3. Check the position of the *mid position marker* and the alignment of the belt and turn the patient back to the starting position.



Note: The electrode 1 is located on the left side of the patient (end with closure holes), the two connector ports from the patient cable point caudally to the right and left sides of the patient.

Close the belt:

1. The belt ends are brought together in the area of the sternum and connected to each other via one of the six closure positions. If possible, use one of the middle closure holes.



Electrode orientation:

If possible, place the electrodes 1 and 16 symmetrically (equidistant) to the sternum (see picture). If possible, place the electrodes 8 and 9 symmetrically to the spine.



The belt does not have to sit too tight, it is crucial that there is sufficient contact between the electrodes and the skin. An offset of the electrodes or an asymmetrically arranged belt can lead to image rotation.



For female patients the belt should be placed onto the breast.

2. Connect the closure snap (C) to the closure stud (sternum).
3. Apply an ECG electrode on the abdomen and attach the reference electrode snap to it.

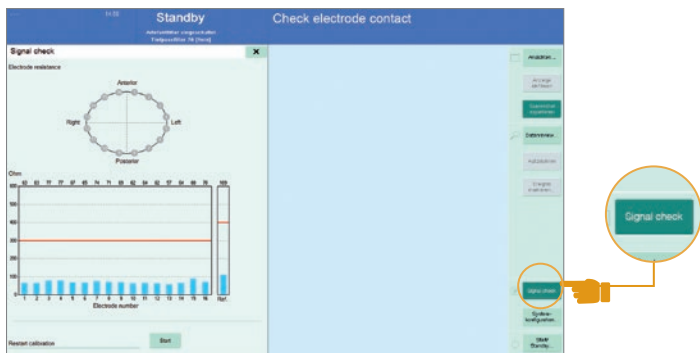


4. Plug-in the trunk cable into the trunk cable port and insert the patient cable plugs into their respective connectors.

Match label and color



1. Select Start/Stand-by screen and choose ›New patient‹.
2. Go to ›Signal check‹ page: the graph shows the skin electrode resistance for each electrode.



The Signal check page. The electrode skin resistance is shown for every electrode.

Each electrode should have sufficient skin contact: Blue bars for every electrode have to be below the red line. If one electrode has bad skin contact (skin electrode resistance $> 300 \Omega$) the respective electrode is highlighted in red.



If the skin electrode impedance is not appropriate add tap water, use electrode gel or wait a few minutes for moisture from the skin to improve the contact. This also applies for the reference ECG electrode.

1.4. SETTINGS BEFORE STARTING AN EIT MEASUREMENT

Before starting the EIT session, it is recommended to go through these steps:

1. Choose ›New Patient‹.
2. Enter patient data.
3. Set frame rate and filter.
4. Select recording mode.
5. Turn on artifact filter.
6. Switch on the contour of the ventilated area.
7. For coupling with a Dräger ventilator configure the Medibus interface.

More detailed information can be found in the instructions for use.

1.5. START THE EIT SESSION

Press the start button. After that the system performs a short calibration (about 30 s) and is then ready for the measurement.



1.6. CHECK THE CORRECT ELECTRODE BELT POSITION

The following procedure will help you to check the belt position or to find the correct position.

The belt is to be placed between the 4th and 6th ICS. For women, the belt should be placed onto the breast.

Case A:

If the belt is placed too far caudally, movements of the diaphragm affect the imaging.

→ **Effect:** Negative impedance changes (see page 34) become visible laterally in the Tidal Image. This is an indicator that the belt is too low.

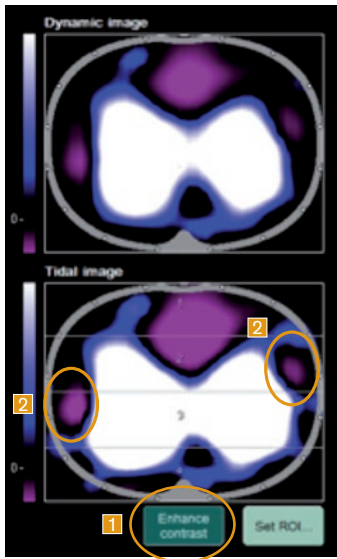
Case B:

If the belt is placed too far cranially, the ventilated lung regions may appear smaller.

→ **Effect:** Due to the low spatial resolution, it is no longer possible to clearly distinguish between the left and right lungs, especially if the mediastinum can no longer be localized in the apical region of the lungs.

Steps to identify whether the belt was placed too low:

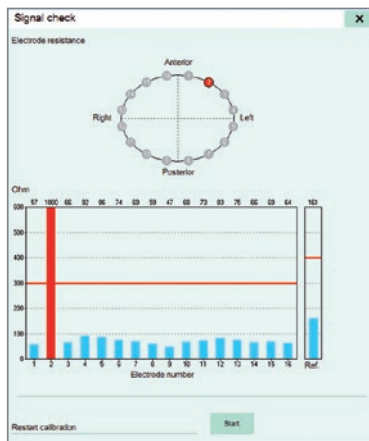
1. Go to the *Main View*.
2. Click the »Enhance contrast button«.
3. If you can see purple regions (negative impedance changes) left and right of the lung regions (blue and white) it is very likely that the belt has been placed too low.
4. Reattach the electrode belt in a more cranial position.
5. Verify, that the purple regions dissappeared.



- 1 Enhance contrast
- 2 Negative impedance changes

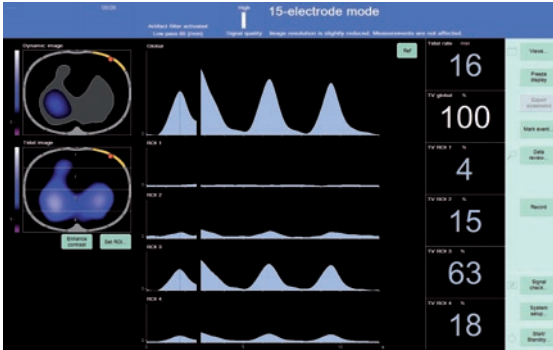
1.7. SPECIAL CASE: 15-ELECTRODE MODE

In the special case that one electrode does not have enough skin contact, the measurement can nevertheless be carried out reliably. The device uses a special mode for this purpose.



If one electrode fails, the message ›Check electrode contact‹ appears, but the measurement can nevertheless be carried out without difficulty

In the so-called 15-electrode mode, the inactive electrode in the virtual thorax contour is marked in yellow. If an electrode fails after starting the measurement, recalibration is required. Then the message ›Electrode contact impaired‹ is displayed, but this does not pose a significant limitation for the measurement.



Measurement in 15-electrode mode

2. Different views and their special properties

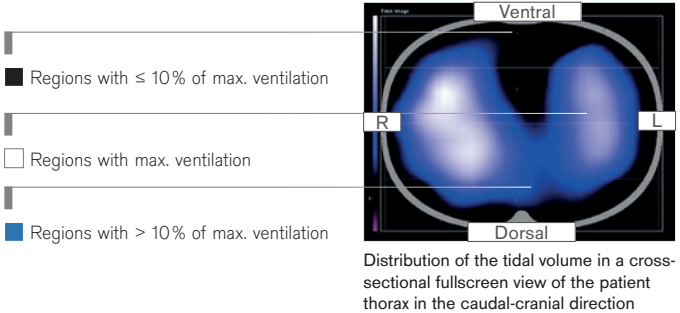
Different views are available for displaying and evaluating the EIT images and image information.

- Main view
- Fullscreen view
- End-inspiratory trend view
- End-expiratory trend ($\Delta EELI$) view
- Diagnostics view

2.1. MAIN AND FULLSCREEN VIEW

After starting the measurement, you are in the **main view**. This view provides an overview of the distribution of the tidal volume in the transverse EIT sensitivity region. In the dynamic image, the volume distribution is displayed in real time at up to 50 fps, inspiratory and expiratory, so inhomogeneities of the lungs can be quickly identified. The *Tidal Image* captures the volume distribution of the last detected breath. To assess regional ventilation during spontaneous breathing

- 1 Dynamic Image
- 2 Tidal Image / Minute Image
- 3 Regions of Interest
- 4 Global Impedance Curve
- 5 Regional Impedance Curves
- 6 Enhance Contrast Button



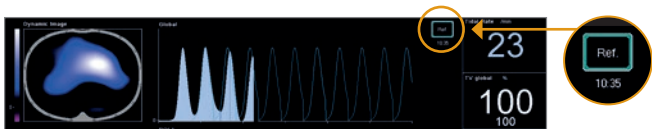
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When looking at EIT images, it should be noted that these are, analogous to CT images, displayed in caudo-cranial projection. We are looking ›from the feet‹ into the lungs.

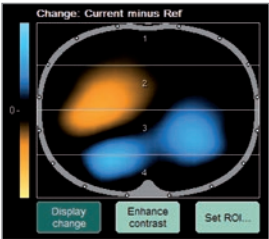
2.1.1. REFERENCING

The reference function is useful, if you want to capture the current condition for comparability prior to a ventilation change or therapeutic intervention. This is activated in the **main view** by the button ›Ref.‹, above and to the right of the *Global Impedance Curve*.



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After activation, a new window, the *Differential Image*, appears instead of the Tidal Image. At the time of referencing, the reference Tidal Image is captured and moved under the Differential Image. Subsequent changes, however, will not be visible until the ›View Change‹ window is activated. In the Differential Image, the current status is compared with the reference status and the differences are displayed. This allows to quickly see areas with an increase or decrease in ventilation. These are illustrated by the following color coding:



Orange = Loss of ventilation
Blue = Gain of ventilation

Differential Image with positive and negative changes.

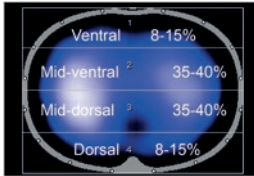
2.1.2. REGIONS OF INTEREST (ROI)

You have the possibility to adjust the ROIs to the current ventilation conditions. Depending on the type of analysis you can choose between layers, quadrants and free arrangements of ROIs. This overview shows typical examples:

ROI Type	Layers	Quadrants	Free
Examination	<ul style="list-style-type: none">• Ventral to dorsal distribution of ventilation• Effects of gravity	<ul style="list-style-type: none">• Localized lung pathologies• Left vs. right lung	<ul style="list-style-type: none">• Heart region• Non-adjacent regions• Single pixels
Examples	<ul style="list-style-type: none">• Dorsal collapse• Ventral overdistension• Positioning	<ul style="list-style-type: none">• Pleural effusions• Pneumothorax• Bronchoscopic mucus removal	<ul style="list-style-type: none">• Analysis of cardiac activity• Detection of fluids

In obese patients the size of the ROIs should be adapted to the smaller tidal image.

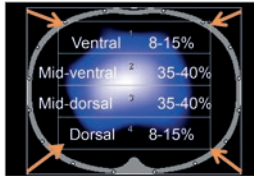
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Healthy patient with normal weight

Window size unchanged, distribution of ventilation in %.

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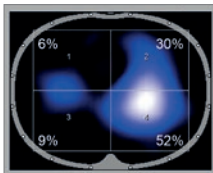


Obese patient

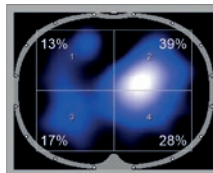
Adjust the window size to the smaller Tidal Image. The sum of the 4 regional tidal variations (TV) should be 100 %.

When comparing the right and left lung the use of ROI quadrants is recommended. As an example, the following image sequence shows the recruitment of the right lung and the percentage increase in tidal volume over time.

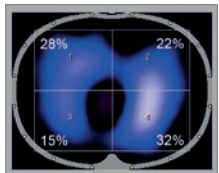
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Before Recruitment Maneuver (RM)



10 Minutes after RM



4 hours after RM

The **fullscreen view** hides the regional impedance curves and enlarges either the dynamic or status EIT image. This view serves to improve the visualization of ventilation.

2.2. TREND VIEWS –

END-INSPIRATORY AND END-EXPIRATORY

The PulmoVista® 500 trend views can be used to compare two different points in time. The **End-inspiratory trend view** is used to compare two different tidal images and their regional tidal volume distribution. It helps you identify inhomogeneities, recruitment, de-recruitment, overdistension and the redistribution of Vt. A trend table shows the regional ventilation distributions (i.e. tidal variations) in % with associated parameters of the ventilator.



- 1** Differential image
- 2** Trend table
- 3** Tidal image Ref
- 4** Tidal image C
- 5** Global impedance curve
- 6** Trend Parameters from ventilator



Set Cursor *Ref* as a reference point and move Cursor *C* to your point of interest to immediately see changes.

- Orange** → Decrease of regional ventilation
- Light Blue** → Increase of regional ventilation

The **End-expiratory trend view** or **Δ EELI-trend view** is used to monitor regional changes of End Expiratory Lung Impedance (Δ EELI). Δ EELI is strongly correlated with changes in End Expiratory Lung Volume (Δ EELV). The Δ EELI trend is useful to assess changes in lung volume for example after changing the PEEP and after recruitment maneuvers for the re-opening of dorsal atelectases as well as for the detection of de-recruitment of individual lung areas.



- 1 Differential image
- 2 Trend table
- 3 Δ EELI global
- 4 Global impedance waveform
- 5 Regional impedance waveforms
- 6 Regional quantification of Δ EELI changes
- 7 Trend parameter from ventilator



Ref and C can be positioned along the time axis. Changes can be seen in the Δ EELI differential image. Areas in orange show a regional decrease (e.g. caused by de-recruitment), areas in light blue a regional increase in EELV (e.g. caused by recruitment).

In the above example, a Δ EELI value of $-0.62 \times TV_{\text{global Ref}}$ means a decrease in end-expiratory lung impedance or EELV by the amount of global tidal variation at Ref, i.e. $0.62 \times V_t$ at location Ref (in this example, this would be 0.62×447 ml). The regional impedance curves show regional changes and the numerical values.

2.3. DIAGNOSTIC VIEW

2.3.1. CONDUCT ANALYSIS DIALOGUE WINDOW

The **Diagnostic View** allows the analysis of regional compliance changes and delays in regional ventilation in addition to the evaluation of ventilation distribution. Every selected time period is called a “section”.

The ›Conduct analysis‹ dialog window is displayed first and should be used to prepare the analysis of a therapeutic maneuver. ›The PEEP trial analysis‹ function enables the automatic analysis of incremental or decremental PEEP maneuvers. In contrast, the ›Customized analysis‹ function enables the evaluation of any other ventilation related intervention.



- 1 Global impedance waveform. If available, trend parameters from the ventilator are displayed: PEEP in green and EIP in pink.
- 2 Sections with alphabetically sorted labels (incl. the respective PEEP if available).
- 3 Automatic section selection.
- 4 Manual section selection (add or remove sections and position them using the touchscreen or rotary knob).
- 5 Define section length (1-10 breaths).
- 6 For the customized analysis you need to define a reference section.
The ensuing analysis quantifies changes in comparison to this section.
- 7 Regional Ventilation Delay (RVD) settings: The RVD is a parameter which displays regional inspiration delays in comparison with global inspiration and may indicate the cyclical collapse and re-opening of lung regions as well as display regionally varying time constants.
- 8 Starting the analysis.



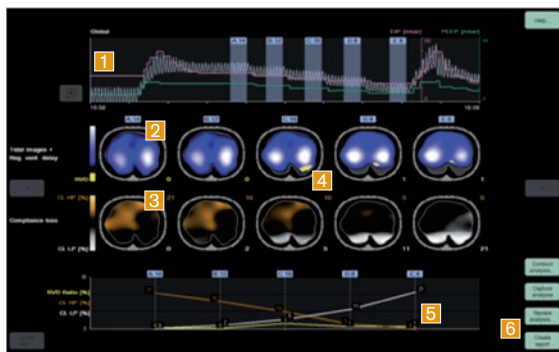
Section settings: Please make sure that one section does not spread over multiple PEEP levels or different interventions. One section always represents the average value of the selected breaths.

2.3.2. RESULTS OF THE ANALYSIS

The results of the PEEP trial analysis support the selection and personalization of PEEP. Regional compliance images show the influence of PEEP on lung mechanics. The ›Customized analysis‹ can be used to evaluate various therapeutic interventions.



At constant driving pressures an increase/decrease in ventilation can be interpreted as an increase/decrease of regional compliance (C).



- 1 Global impedance waveform and sections. If available, trend parameters are displayed: PEEP in green and EIP (or PIP) in pink.
- 2 Tidal Image for every displayed section.
- 3 Compliance loss image for every displayed section.
- 4 Areas in which a regional ventilation delay was detected and corresponding RVD parameter, displayed in yellow.
- 5 Diagram with the numeric values of all sections depending on the settings and analysis type.
- 6 Create report: An image and a text file are created containing the entered parameters, the event list, all available analysis parameters and MEDIBUS values, and a screenshot of the analysis. (Only active if a USB mass storage device is connected). This report is meant to be used for documentation purposes.



The RVD parameter can be displayed in 2 different configurations: as the standard deviation of the RVD (RVD SD) for every section or as the RVD Ratio. RVD SD, indicated as % of T_i , describes how inhomogeneous the regional inspiration within the contour of the ventilated area is. RVD Ratio, indicated as % of the total number of pixels, describes the ratio of the pixels with RVD to the total number of pixels within the contour of the ventilated area.



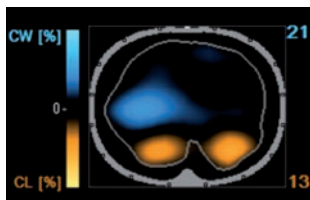
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Colour maps – PEEP trial analysis

Dark Grey: Pixels with highest compliance.

Orange: Decrease of compliance towards higher PEEP levels – This typically occurs in ventral regions at high PEEP levels and may be interpreted as overdistension. The parameter CL HP of 10 means, that there was a cumulative decrease of 10 % in those (orange) regions, while the highest compliance was identified at a lower PEEP value.

White: Decrease of compliance towards lower PEEP levels – This typically occurs in dorsal regions at low PEEP levels and may be interpreted as collapse or derecruitment. The parameter CL LP of 5 means, that in this image there was a cumulative decrease of 5 % in those (white) regions, while the highest compliance was identified at a higher PEEP value.



Colour maps – Customized analysis
Compliance Loss / Compliance Win

Dark Grey: Pixels with no change against Reference.

Orange: CL - Decrease of compliance against Reference

CL = 13 means, that in this image there was a cumulative decrease of 13 % in those (orange) regions.

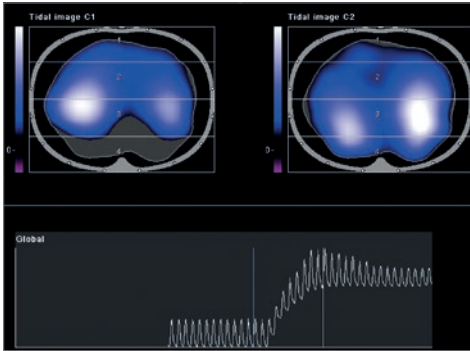
Turquoise: CW - Increase of compliance against Reference

CW = 21 means, that in this image there was a cumulative increase of 5 % in those (turquoise) regions.

3. Useful Tools and Tips

3.1. CONTOUR OF VENTILATED AREA

With the help of the ›contour of ventilated areas‹, it is possible to track the ventilated lung regions in form of a virtual footprint. The contour allows the delimitation of the ventilated regions per breath and the identification of lung regions with e.g. restricted ventilation or delayed inspiratory procedures. The setting of the contour of ventilated area is located in the setup menu ›Display‹. The contour is displayed in the dynamic image (main view, fullscreen) as well as in the end-inspiratory trend. In the dynamic image the contour represents the area of the last detected breath. In the end-inspiratory trend view, this contour marks all the ventilated lung regions in the selected observation period (1 min - 120 min). Depending on the cursor position (*Ref*, *C*), non-ventilated areas are marked in grey.



Grey areas indicate lung regions that are not ventilated at time *Ref* or *C* but have been ventilated at a different time within the selected observation period. In the picture above, the grey area at time *Ref* identifies the recruitable lung area at time *C*.

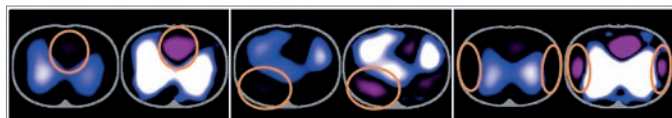
3.2. NEGATIVE IMPEDANCE CHANGES

Negative impedance changes (in black/purple) represent inverted waveforms and are often caused by fluid accumulations inside the thorax.

The following conditions might cause negative impedance changes:

- Heart activity
- Pleural effusion
- Movement of the diaphragm (belt placed too low, see page 18)
- Artifacts (e.g. body movement, repositioning of the belt, strong electromagnetic fields)
- Deeper expiration than inspiration
- Pendelluft

D-11906-2017



Heart / Mediastinum

Pleural effusion

Movement of the diaphragm

3.3. FILTRATION

By default, PulmoVista® 500 processes unfiltered raw data and displays it accordingly. Since even smallest changes are detected with this technology, it is also possible to display simultaneous superimposed effects. Thus, e.g. pulmonary function as well as cardiac or perfusion related impedance changes are displayed. A functional pulmonary EIT might be better interpreted if superimposed effects, such as those caused by the cardiac function, are filtered out. For this purpose, the device has filter options such as *low-pass* and *band-pass filters*, with which a targeted suppression of impedance signals is possible. This option can be set in the menu under ›Display‹.

Low pass filter: Display of impedance changes below a certain frequency
 Example: Only respiratory signals are of interest, i.e. signals with a frequency in the range of the respiratory rate but below the heart rate, e.g. $HR - 20$.

Band pass filter: Display of impedance changes within a certain frequency range
 Example: Only cardiac-related impedance signals are of interest, e.g. signals with a frequency of $HR \pm 20$.

Electromagnetic radiation causes artifacts that make it difficult or even impossible to qualitatively evaluate EIT images. Artifacts can negatively affect the baseline at the end of expiration that interpretation of the tidal images is no longer possible.

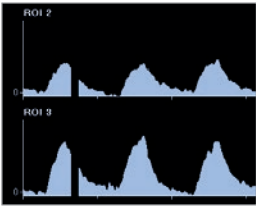
Special filter techniques of PulmoVista® 500 allow the elimination of image artifacts, making EIT images interpretable again. The setting can be found in the menu item ›Display‹.



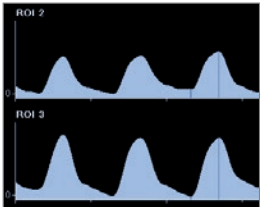
Recommendation: Leave the artifact filter turned on.



Filter menu



Unfiltered EIT data



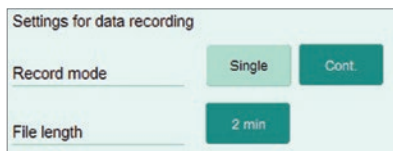
Filtered EIT data with low pass filter at HR -20



Please note that *low-pass and band-pass filtering* may cause a phase shift and thus a delayed display of impedance curves. With activated bandpass filtering the tidal rate will no longer be displayed. Filter and boundary frequency settings only affect the display of data, not on the data recording.

3.4. SAVE SCREENSHOT AND RECORD EIT DATA

You can take screenshots and record entire EIT measurements (EIT data). For creating screenshots, insert a USB flash drive into one of the side USB ports in the C500 monitor. After pressing the key ›Export Screenshot‹ the current view will be transferred directly onto the flash drive. If you want to make sure that a specific image is captured you can freeze the image by using the function ›Freeze display‹. A recording of EIT files (option ADAP required) is possible with the following options:



Single file or continuous recording



The recording file length is between 30s and 10 min. To record, press the button ›Record‹. You can cancel the recording at any time by pressing this button again. The recorded files can be analyzed by using the function ›Data Review‹ or by loading them as a simulation file. Via the menu ›Data recording/File handling‹, the data can be deleted or transferred to a USB flash drive. In the menu ›File‹ the free hard disk space as well as the available USB storage space is indicated.

3.5. COUPLING OF A DRÄGER VENTILATOR WITH PULMOVISTA® 500

PulmoVista® 500 allows a synchronous import of EIT information and the current ventilation settings, waveforms, and trends. Data is imported via the Medibus/ Medibus.X interface. The necessary settings can be found in the menu under ›Screen layout/Data Import‹. For data transmission, the following settings must be made at the ventilator:

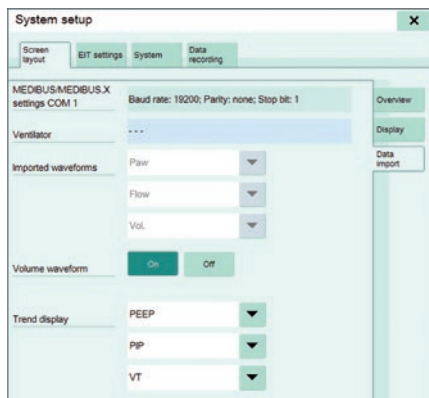
Baudrate: 19200

Parity: non

Stopbit: 1



The data cable is connected to the COM1 port of PulmoVista® 500. After successful pairing, the ventilator name is displayed in the menu.



Data import menu with configuration of curves and parameters for trend views

3.6. FRAME RATE

The dynamic EIT image continuously shows relative impedance changes. The high temporal resolution of this method allows for very precise analysis of individual phases during inspiration and expiration as well as the detection of rapid changes in intrathoracic processes. This is useful for assessing regional ventilation even at high respiratory rates, such as HF ventilation, as well as for measuring higher-frequency processes, such as cardiac activity. In the ›EIT Settings‹ menu, you can adjust the frame rate, i.e. the number of EIT images generated per second.

Adjustable frame rate = 10 – 50 Hz (pictures /s)

By default, the frame rate is 20 Hz

4. Clinical Application

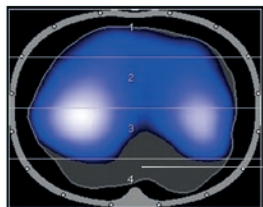
Chest EIT opens up new possibilities for everyday clinical practice in addition to already established technologies. For more than 10 years, the significance of EIT has been demonstrated by numerous clinical studies. In this regard, after years of research the next logical step is the transfer of EIT into the clinical routine. EIT provides new and additive information and allows the personalization of ventilation.

4.1. IDENTIFY RESPONDER OR NON-RESPONDER TO A RECRUITMENT-MANEUVER (RM)

Step 1: Perform a RM

Open the **Main View**: Set the Regions of Interest to »layers« (adjust their height if required: in obese patients, adjust the height of the ROIs, so that ROI 1 properly represents ventral ventilation)

- Check if RM might improve homogeneity of ventilation: Is dorsal TV in ROI 4 < 5 %?
- If TV in ROI 4 suggests collapse: Perform a recruitment maneuver according to hospital standards



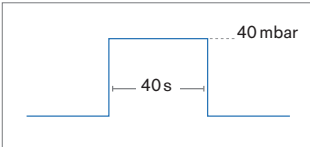
TV ROI 4 < 5 %?



As the individual response of each patient might vary a lot, RMs should be assessed in every single patient!

Look out for:

- Volemic status of the patient
- Cardiac function
- Other side effects / complications

EXAMPLE: 40:40 MANEUVER

Inspiratory hold:

Inspiratory pressure of 40 mbar for 40 s

Recruitment-Maneuver**Objective:**

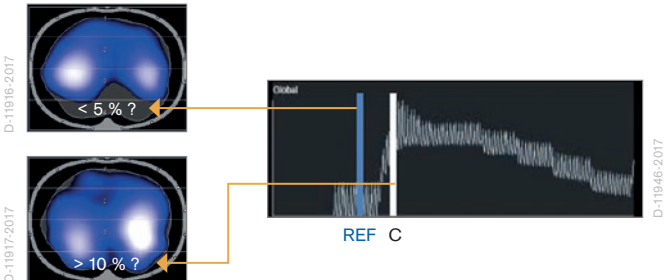
- Re-expand collapsed lung tissue
- Maintain sufficient PEEP to prevent de-recruitment after RM

How-to:

- Increase end-inspiratory pressure (P_{insp}) for a short time
- Impose sufficient pressure to exceed the critical opening pressure of the affected lung region and to recruit non ventilated or poorly ventilated lung tissue

Step 2: Assess with PulmoVista® 500 if maneuver could open the lung**1. Open the End-inspiratory Trend View:**

Compare the status before (*Cursor Ref*) and during the RM (*Cursor C*).



2. Identify responder or non-responder:

Responder:

TV in ROI 4 is significantly higher during the RM than before (e.g. TV ROI 4 – 10 %, and the differential image shows light blue color in ROI 4.

Non-Responder:

Small or no change in ROI 4 (\pm 0 – 2 %)


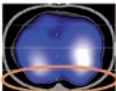
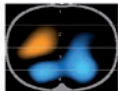
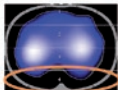
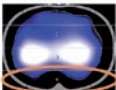
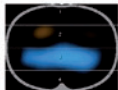
What to look for in the End-inspiratory Trend View?

The following table shows two different results of a recruitment maneuver.

The first case shows a responder with a PIP of 34 mbar to open the dorsal areas in ROI 4 (TV 1 % => 13 %). The differential image highlights this increase of ventilation in the blue areas.

In contrast, the second case, a non-responder, shows only a minimal increase in dorsal ventilation in ROI 4 (TV 4 % => 5 %), despite the relatively high PIP of 41 mbar. A significant increase in ventilation can be seen in ROI 3, due to a significant increase in tidal volume from 434 ml to 861 ml.

In both cases a PEEP of 15 mbar was applied.

Examples	Ref. Tidal Image before RM	C: Tidal Image during RM	Differential Image	Trend table															
Responder to higher pressures				<table><tr><td></td><td>Ref</td><td>C</td></tr><tr><td>TV ROI 4 [%]</td><td>1</td><td>13</td></tr><tr><td>PEEP [mbar]</td><td>5</td><td>15</td></tr><tr><td>PIP [mbar]</td><td>20</td><td>34</td></tr><tr><td>VT [mL]</td><td>660</td><td>790</td></tr></table>		Ref	C	TV ROI 4 [%]	1	13	PEEP [mbar]	5	15	PIP [mbar]	20	34	VT [mL]	660	790
	Ref	C																	
TV ROI 4 [%]	1	13																	
PEEP [mbar]	5	15																	
PIP [mbar]	20	34																	
VT [mL]	660	790																	
Non-responder to higher pressures				<table><tr><td></td><td>Ref</td><td>C</td></tr><tr><td>TV ROI 4 [%]</td><td>4</td><td>5</td></tr><tr><td>PEEP [mbar]</td><td>7</td><td>15</td></tr><tr><td>PIP [mbar]</td><td>17</td><td>41</td></tr><tr><td>VT [mL]</td><td>434</td><td>861</td></tr></table>		Ref	C	TV ROI 4 [%]	4	5	PEEP [mbar]	7	15	PIP [mbar]	17	41	VT [mL]	434	861
	Ref	C																	
TV ROI 4 [%]	4	5																	
PEEP [mbar]	7	15																	
PIP [mbar]	17	41																	
VT [mL]	434	861																	

4.2. IDENTIFY POSSIBLE DE-RECRUITMENT AND OVERDISTENSION

Principle: Comparison of regional compliance at different PEEP levels

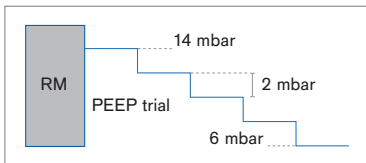
Use the PEEP trial analysis to interpret the loss of compliance.

Step 1: Perform a decremental PEEP trial

According to hospital standards.

EXAMPLE: DECREMENTAL PEEP TRIAL

- Initial recruitment maneuver
- PEEP steps of 2 mbar
- Driving pressure ΔP ($P_{\text{Plat}} - \text{PEEP}$) should remain constant



Definition of derecruitment:

A loss of ventilation towards lower PEEP levels indicates the onset of derecruitment. This reduced ventilation can be caused by going below the alveoli's closing pressure and the subsequent collapse of alveoli. This phenomenon is often accompanied by a low end-expiratory lung volume in these regions.

Definition of overdistension:

The term overdistension describes an excessive expansion of the alveoli, which is very often caused by either high tidal volumes and/or high end-expiratory lung volumes resulting from high PEEP levels.

In EIT, overdistension can be expected whenever a major loss of ventilation is observed during PEEP trials in the non-dependent lung areas towards higher airway pressures. During pressure controlled ventilation this loss of ventilation can also be interpreted as reduction of regional compliance.

Step 2: Perform PEEP trial analysis

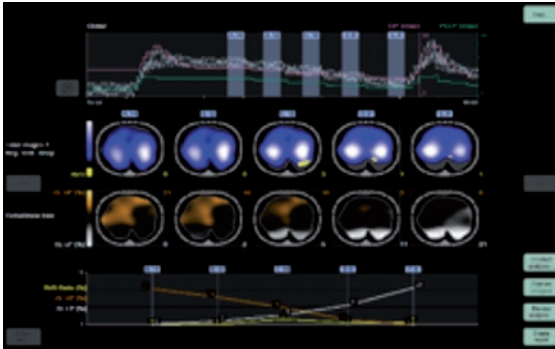
1. Prepare analysis

Make sure that every PEEP level is represented by one section of appropriate length. Manually adjust section positions if necessary.



2. Perform analysis

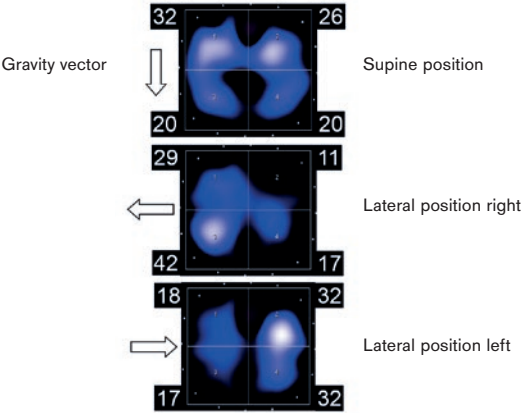
Compliance changes during PEEP trials are conveniently displayed as a series of images and a diagram. At lower PEEP levels, those compliance changes may indicate collapse, at higher PEEP levels overdistension, respectively. Based on this information, an individualized PEEP level can be chosen, where the loss of compliance and the underlying adverse effects are minimized.



D-30765-2017

4.3. INFLUENCE OF POSITIONING ON THE DISTRIBUTION OF VENTILATION

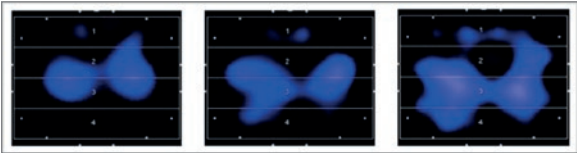
The positioning of a body has an influence on the ventilation of the lungs. The change in ventilation can be visualized with PulmoVista® 500. Whether and to what extent patient positioning promises success depends on the individual status of the patient, but the effect can be seen immediately after the situation at EIT has changed. Here is an example of a healthy lung during natural spontaneous breathing. The ventilation distribution of a mechanically ventilated patient with impaired respiratory function will be exactly reversed. The arrows represent the gravity vectors, the numbers represent the regional distribution of ventilation.



4.4. PATIENT PRONING

PulmoVista® 500 allows the visualization of ventilated and non-ventilated lung areas. It is therefore also suitable for visualizing and tracking changes in ventilation following the application of any therapeutic intervention, such as after patient proning.

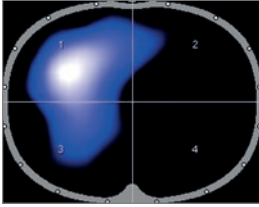
Initial Condition 20 min. after 1st proning trial 20 min. after 2nd proning trial



4.5. INTUBATION CHECK

PulmoVista® 500 can help to detect a faulty tube position. Real-time information helps EIT identify the correct tube position during the intervention.

D-11910-2017

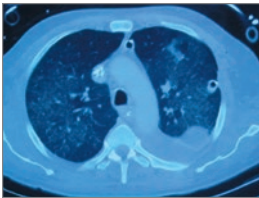


Example: ET tube inserted too deeply → ventilation visible only in right lung

4.6. PATIENT WITH PLEURAL EFFUSION

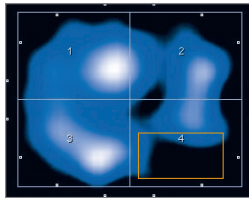
The following example shows the effect of an area with fluid accumulation in the lungs, here in the case of a pleural effusion. The marked area is not ventilated and as long as there are no changes, this region remains ›black‹.

D-3430-2011



Pleural effusion in CT-Image

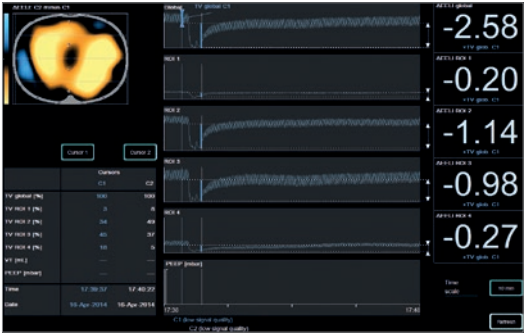
D-54-2011



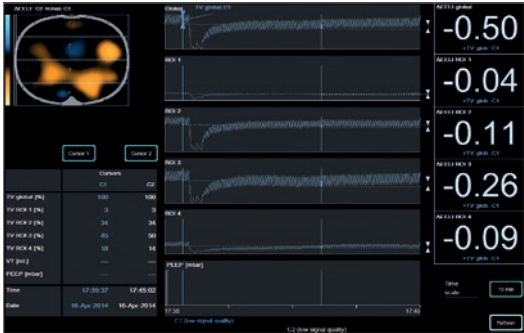
Pleural effusion in EIT-Image

4.7. ΔEELI-TREND AFTER SUCTION

The ΔEELI trend is predestined to visualize and evaluate end-expiratory events in the lungs. In this case, a secretion suction was performed, which initially resulted in a sharp drop in end-expiratory lung impedance (EELI) (-2,58 x TVglob. C1).



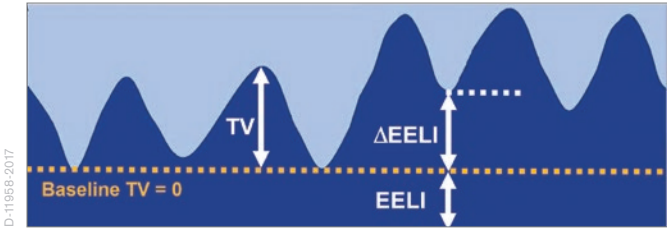
After about 5 minutes, there is a significant increase in EELI globally and regionally, but the original state has not yet been reached again (-0,5 x TVglob. Ref).



5. EIT-Terminology

Baseline:

Sets the reference for the next breath or sequence of breaths (changes in impedance). The virtual baseline EIT image in the different views is black.



Globale Impedance Curve

ΔEELI = Changes of EELI:

Changes in end-expiratory lung impedance in the EIT sensitivity region. Absolute impedance measurements cannot be directly related to end-expiratory lung impedance. Nevertheless, ΔEELI is strongly correlated to changes in the end-expiratory lung volume within the EIT sensitivity region. The PulmoVista® 500 parameter ΔEELI expresses regional end-expiratory lung impedance variations compared to the global tidal variation of Cursor Ref.

EELV = end-expiratory lung volume:

EELV is often used interchangeably with the term FRC. However, mechanically ventilated patients exhale against PEEP and not against ambient pressure. Therefore, physicians use the term EELV instead of FRC.

FRC = functional residual capacity:

FRC is a physiological parameter that describes the residual volume of lung capacity at the end of passive expiration (against ambient pressure). EELV (or FRC) describes the volume of air that can contribute to gas exchange between breaths.

Negative impedance change:

Negative impedance changes are displayed in black or purple. They represent inverted waveforms and are often caused by fluid accumulations inside the thorax.

ROI = Region of Interest:

Arrangement of regions for quantitative analysis of EIT images.

Tidal image:

The Tidal Image represents the tidal volume distribution of one entire breath from the end of expiration to the end of inspiration.

TV = Tidal Variation:

Increase in impedance during inspiration, correlates to the tidal volume V_T .

TV global represents the tidal variation between the minimum value and the maximum value in the global impedance curve for each breath. Regardless of the tidal volume, this value is always 100 %, it merely serves as a reference for the tidal variations of the ROI.

TV ROI:

Regional tidal variations indicate the percentage of the ventilation-related impedance change that occur in the corresponding ROI.

6. Contraindications

- Patients with pacemakers, defibrillators or other electrically active implants
- Patients with damaged skin or impaired skin contact of the electrodes due to wound dressings (PulmoVista 500 could also work in “15-electrode mode”)
- Patients where the attachment of the patient belt could pose a risk to the patient, e.g. patients with spinal lesions or fractures
- Patients with uncontrolled body movements
- Use during electricity-based therapies, such as electrosurgery or electrocautery
- Use in the presence of strong magnetic fields, e.g. MRI
- Use the in conjunction with other bioimpedance measurement devices
- Safety and effectiveness have not been established in pregnancy
- Not validated for patients with tidal volumes smaller than 1 ml/kg bodyweight or a body mass index above 50
- Images from extremely obese patients or those with massive lung edema must be interpreted with care as signal quality may be affected

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