CARESCAPE R860
Nutritional Assessment
Tools Appliguide
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Introduction

Scope of this appliguide
This appliguide covers the following clinical tools available with the CARESCAPE R860 ventilator:
Indirect Calorimetry or Metabolics

Structure of this appliguide
This appliguide follows the following structure to guide you at the bedside application of these measurements and allow you to implement data driven and patient specific strategies for optimum ventilation.

Chapter 1: Indirect Calorimetry,
Some concepts of Indirect Calorimetry that help in understanding how to perform optimum measurements

Chapter 2: Limitations of Indirect Calorimetry
Knowing when it is not possible to carry out Indirect Calorimetry measurements

Chapter 3: Understanding Steady State
A vital concept to ensure that measurements collected at the patient’s airway reflect cellular metabolism

Chapter 4: Ensuring accurate measurements with the Respiratory Gas Module
Tip on how to ensure optimum airway measurements

Chapter 5: Finding Steady State with the CARESCAPE R860
The specialized tool to probe for steady state and easily comply with Indirect Calorimetry guidelines

Chapter 6: Indirect Calorimetry workflow and checklist
To measure the caloric output and assess the metabolic status and energy expenditure of the ventilated patient, a technique called Indirect Calorimetry is used in the CARESCAPE R860 equipped with a suitable Respiratory Gas Exchange Module.

Always refer to the User Reference Manual before use.
Indirect Calorimetry

In the past such measurements have been carried out by direct calorimetry. Direct calorimetry requires the test subject to be placed in a thermally isolated chamber in order to capture the total body heat output. Even though this technique was used to establish the principles of metabolic assessment, it has no practical use in the ICU. Instead of measuring the heat output of the body, Indirect Calorimetry calculates the total Energy Expenditure (EE) and Respiratory Quotient (RQ) by measuring Respiratory Gas Exchange i.e. the consumption (or uptake) of O$_2$ (VO$_2$) and production (or elimination) of CO$_2$ (VCO$_2$) which are the result of oxidation (burning) of food and nutrients to generate energy for the human body.

The following equations are used by the CARESCAPE R860 to calculate EE from the measured VCO$_2$ and VO$_2$ (modified Weir formula)

EE adult (kcal/day) = 5.5x VO$_2$ (ml/min) + 1.76x VCO$_2$ (ml/min) - 1.99 x UN (g/day)

EE pedi (kcal/day) = 5.5x VO$_2$ (ml/min) + 1.76x VCO$_2$ (ml/min)

RQ = VO$_2$/VO$_2$ (please see statement about steady state in subsequent text)

(UN is Urea Nitrogen excretion and is assumed to be 13 g/day for adults only)

The fact that this method is indirect introduces several limitations which need to be well understood by the physician who will use the provided data as well as by the clinicians who will help generate such data. Every clinician using Indirect Calorimetry should understand and account for its limitations, before reporting and interpreting results.

The limitations of Indirect Calorimetry stem from both human physiology and the way Energy Expenditure (EE) and Respiratory Quotient (RQ) are measured.

*Figure 1: Indirect Calorimetry Measurements*
The human body relies on the blood circulation to transport O$_2$ and CO$_2$ from the lungs to the tissues. In order to probe and measure a valid reflection of cellular metabolism indirectly via Respiratory Gas Exchange, we have to consider the following:

1. That there is no loss or addition of CO$_2$ (and O$_2$) between the tissues where cellular metabolism takes place and the monitoring site at the patient’s airway.

2. That VCO$_2$ and VO$_2$ are measured under such conditions and for sufficient time to account for the buffering capacity of the cardio-respiratory system when respiratory and/or hemodynamic status changes.

Figure 2: An Illustration showing the role of the CO$_2$ and O$_2$ pools of the body in gas exchange

In conclusion the results obtained from gas exchange measurements are reflecting actual metabolic quantities only when the CO$_2$ and O$_2$ pools of the body are in steady state (see Figure 2). In a general case, the precise terms to describe gas exchange are CO$_2$ elimination (VCO$_2$) and O$_2$ uptake (VO$_2$) measured at the patient airway and their ratio VCO$_2$/VO$_2$, which is called Respiratory Exchange Ratio. For sake of simplicity, and according to general practice, we state Respiratory Quotient (RQ) when in fact we measure Respiratory Exchange Ratio, i.e. steady state conditions are assumed.

The following sections discuss in more detail the limitations of Indirect Calorimetry when measured with the CARESCAPE R860 equipped with a suitable gas exchange module on intubated and mechanically ventilated patients.
Limitations of Indirect Calorimetry

Leaks
Indirect Calorimetry uses measured VO$_2$ and VCO$_2$ (minute volumes of consumed O$_2$ and produced CO$_2$) to calculate Energy Expenditure (EE) and Respiratory Quotient (RQ). In order to have a representative result the device must measure all the O$_2$ consumed and all CO$_2$ produced. Any leaks

- in the ventilator circuit or
- around the artificial airway (endotracheal or tracheostomy tube)
- parenchymal leaks in the lung from fistulas, pneumothorax or chest drains etc.

will affect the measurement. For this reason measuring a patient ventilated in NIV (noninvasive mode) via a mask or other NIV interface is not advisable. Leaks should be probed prior to IC measurements and eliminated as much as possible.

Blood filtration
For the same reason as above Indirect Calorimetry may provide inaccurate data during hemodialysis or peritoneal dialysis.

N$_2$O and other gas mixtures
Indirect Calorimetry cannot be performed in the presence of N$_2$O. Please note that the elimination of N$_2$O from the body and also from diffusion is not immediate and patients should not be measured during or immediately after anesthesia involving N$_2$O.

In general Indirect Calorimetry measurements should not be performed if there are any other gases apart from Air/O$_2$ are present at the airway.

FIO$_2$ > 85%
VO$_2$, which is one of the input variables in calculating Energy Expenditure and RQ, has a measurement accuracy which depends on FiO$_2$. The higher the FiO$_2$, the lower the VO$_2$ accuracy. This is due to a mathematical calculation employed called Haldane transformation and it is not a reflection of changing inaccuracy of the oxygen and flow sensors. For most accurate results, FiO$_2$ should be less than 65%.

Limitations due to Respiratory Gas Module Specifications
There are limitations as regards to the maximum rate and minimum tidal volume that the Respiratory Gas Module can measure. Please check the appropriate specification sheet.

Breath rate > 35 bpm
Tidal Volume < 200 ml D-lite(+) or < 15 ml Pedi-lite(+)
After accounting for all the above mentioned limitations the user of Indirect Calorimetry has to establish that the measurements have been obtained at what is known as steady state. When the patient is at steady state the measured VO\textsubscript{2} and VCO\textsubscript{2} and their ratio will reflect the Energy Expenditure and Respiratory Quotient at the cellular level. If the patient is not at steady state the calculated EE and RQ could be under or over estimating the actual cellular level metabolic processes.

For this reason Indirect Calorimetry measurements should be obtained from as long a measuring period as possible and at such times in the day where there are the least amount of patient stimuli. However even if all indications point to a stable patient the Respiratory Gas Exchange and ventilation parameters trended data should be observed on the ventilator/monitor screen in order to assess steady state. Through the ventilator/monitor trend displays it is possible to observe the variations of VCO\textsubscript{2}, VO\textsubscript{2}, RQ, MV and Respiratory Rate over time and determine the steady state period or periods. There are good clinical practices for Indirect Calorimetry which maximizes the chances of a patient being at steady state and make using Indirect Calorimetry easier.

**Maximizing the chances of Steady State**

In order to ensure steady state to the extent possible avoid the following:

- Ventilator setting changes during and prior to IC measurements. Any change of minute volume, PEEP and especially FiO\textsubscript{2} will result in changes of VO\textsubscript{2} and VCO\textsubscript{2} hence EE and RQ which are not due to the underlying metabolism. The recommendation is to avoid any ventilator settings for about 1 to 2 hours prior to the IC study.

- Avoid measurements during times that there are stimuli which can cause patient discomfort and alter the respiratory status, like bronchial suction or other nursing interventions and patient activity.

All the above mentioned points are inherent in the technique of Indirect Calorimetry and apply in general no matter which type of IC instrumentation is used. The following apply specifically to the Respiratory Gas Module from GE Healthcare.
Ensuring accurate Respiratory Gas Module measurements

Managing humidity in the patient circuit

If active humidification is used instead of an HME (Heat and Moisture Exchanger) type humidifier it is important that the D-lite sensor and the sampling tubes remain free from condensation. Condensation in the sampling tubes can affect the flow/volume measurements and/or the gas composition measurements.

During ventilation with active (heated) humidification, it is recommended to use D-lite(+) and Pedi-lite(+).

D-lite (+) and Pedi-lite(+) sensors have a hydrophobic coating to repel condensation from its inner surface and minimize possibility of entry in the sampling tubes.

If an active (heated) humidifier is used ensure that the sampling tubes are on the top and that the D-lite+ or Pedi-lite+ sensor is placed at a 20 – 45 degrees tilt to minimize chances of condensation entering the sampling tubes and interfering with the measurements.

Figure 3: Minimizing the effects of humidity in the airway gases

Condensation and droplets in the sampling tubes will create sudden and large inaccuracies and variations especially in the volume measurements and as such they are easy to detect. Display module volume measurements and compare with ventilator set/measured volumes to ensure that they are comparable (although very rarely will they be identical).

If an HME (Heat and Moisture Exchanger) is used ensure that it is placed between the D-lite sensor and the patient.

Figure 4: Correct position of an HME device
Bias Flow dilution effect

Several ventilators today employ a continuous flow through the patient circuit for triggering and response latency purposes. Such flows could interfere with the gas measurements by mixing patient gas and fresh gas during long expirations. This condition can be observed by looking at the shape of the CO₂ waveform.

A further indication that this effect might be playing a role is obtained by observing the patient’s flow waveform: Periods of zero flow at the end of expiration indicate higher chances of this dilution effect.

In this example the effect of high bypass flow is visible:

- Message on the digit field
- Double slope on the CO₂ curve at the start of inspiration

To minimize this dilution effect, add a 5 ml dead space between the circuit “Y” piece and the D-lite sensor if this increase of dead space is not deemed to be detrimental to the patient’s ventilation.

The CARESCAPE R860 has a special view under Clinical Decision Support to assist in finding steady state after a period of gas exchange measurements.
Finding Steady State

The view displays the relevant graphical trends and has an adjustable and sliding averaging window which assists in probing stable measurement periods and observing the averaged EE and RQ values together with the associated coefficients of variation to be able to ensure adherence to various steady state guidelines.
<table>
<thead>
<tr>
<th>Workflow Step</th>
<th>Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>No limitations for the measurement</td>
<td>• FiO\textsubscript{2} &lt; 85% (ideally &lt;60%)</td>
</tr>
<tr>
<td></td>
<td>• Breath Rate &lt; 35 bpm</td>
</tr>
<tr>
<td></td>
<td>• Tidal Volume &lt; 200 ml D-lite(+) or &lt; 15 ml Pedi-lite(+)</td>
</tr>
<tr>
<td></td>
<td>• N\textsubscript{2}O and O\textsubscript{2} mixture in patient gas</td>
</tr>
<tr>
<td></td>
<td>• No leaks due to fistulas, chest drains etc.</td>
</tr>
<tr>
<td></td>
<td>• Blood filtration</td>
</tr>
<tr>
<td>Maximize patient conditions to achieve Steady State</td>
<td>• No recent ventilation settings changes</td>
</tr>
<tr>
<td></td>
<td>• No recent or planned patient nursing interventions</td>
</tr>
<tr>
<td></td>
<td>• Patient has stable temperature and is hemodynamically stable</td>
</tr>
<tr>
<td>Ensure accurate COVX gas measurements</td>
<td>• Allow the module to warm up for 30 mins prior to measurements</td>
</tr>
<tr>
<td></td>
<td>• Select appropriate D-lite sensor according to patient population and</td>
</tr>
<tr>
<td></td>
<td>humidification used</td>
</tr>
<tr>
<td></td>
<td>• Manage angle of the D-lite sensor to eliminate condensation.</td>
</tr>
<tr>
<td></td>
<td>• Verify that bias flow is not diluting gas measurements</td>
</tr>
<tr>
<td></td>
<td>- Add spacer if required</td>
</tr>
<tr>
<td></td>
<td>• Check and eliminate patient circuit leaks</td>
</tr>
<tr>
<td></td>
<td>- Verify and inflate correctly artificial airway cuff</td>
</tr>
<tr>
<td></td>
<td>• Ensure that the gas module has been calibrated according to recommendations in the User Reference Manual</td>
</tr>
<tr>
<td>During measurements monitor that humidity and condensation is not affecting results</td>
<td>• Display gas module inspiratory and expiratory tidal volumes</td>
</tr>
<tr>
<td></td>
<td>- Compare these values with ventilator set and/or measured volumes.</td>
</tr>
<tr>
<td></td>
<td>• Display VO\textsubscript{2}, VCO\textsubscript{2} and RQ measurements on the screen as quality indicators during the measurement. Physiologically one does not expect large variations in these values due to metabolic reasons over short periods of time (~1 hour).</td>
</tr>
<tr>
<td></td>
<td>• Ensure that ventilator settings are not changed during the course of IC measurements</td>
</tr>
<tr>
<td>Report measurements when patient is at steady state</td>
<td>• Display the Indirect Calorimetry (Metabolics view) and select averaging window either according to guidelines or by enlarging it to cover a stable measurement area.</td>
</tr>
<tr>
<td></td>
<td>• Probe stability by sliding the averaging window while observing VO\textsubscript{2} and VCO\textsubscript{2} Coefficients of Variation (CVI)</td>
</tr>
<tr>
<td></td>
<td>• Record the averaged EE and RQ data and press the save key to save the data and the selection to the unit trend memory.</td>
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