Inspire

A New Perspective on Respiratory Rate Monitoring
Safety and Security

In 2002, Michael Script invented a non-spinning gyroscopic analog sensor, primarily used for object detection.

The concept of multi-sensor array using a collection of Smart Object Sensors was developed in 2007.

By 2009, this sensor array became the foundation for counting respiratory rate.
**WHAT DO WE KNOW AS FACT(.)**

Common respiratory values for Children  
*Age by Breaths per minute*

- Infant 30 or more
- Child 22-28
- Adolescent 16-20
- Adult - normal 14-18*
- Adult - abnormal <10 and >20

*It has been shown that women typically have higher respiratory rates than men.*
Measuring Respirations
The respiratory rate is the number of breaths that a patient takes each minute. The rate should be taken when the patient is at rest, and it is assessed by counting the number of times the chest rises in one minute. Common factors that influence respiration rate are as follows:

- Age and Emotional status
- Air Quality and Altitude
- Exercise and Internal temperature
- Disease (i.e., cardiopulmonary)
- $O_2$ and $CO_2$ level (i.e., pulmonary status)
- Effectiveness of Breathing Pattern
Who is the Patient?

Infants and Children living in developing countries, visited in remote areas, away from clinical settings and professional care.

Usually diagnosed and treated in the field by locals trained in best practices.
Who is the Health Care Worker?

Locally provisioned or remotely NGO educated residents.

Equipped with a stop watch or counting beads.
What is your best guess for breath rates for either patient being displayed. Talking or grunting can reduce the breath rate by 70% in adults and children.
Is One Enough?

Can one sense or sensor accurately detect and count breath rate?

Understanding the variability in the Gold Standard even under optimal conditions and then restricting any one of those variables for Respiratory Rate Counting presents a new set of conditions that need to be considered.

- Body Position
- Temperature
- Anxiety Level
- Heart Rate
- Skin Condition
- Device Stability
## Working with Device Variables

<table>
<thead>
<tr>
<th>Environment</th>
<th>Radical Weather swings from Bangkok to Buffalo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
<td>Remote</td>
</tr>
<tr>
<td>Lighting (Solar)</td>
<td>Varies from zero to Maximum</td>
</tr>
<tr>
<td>Body Position</td>
<td>Potentially each of Fowler’s Positions</td>
</tr>
<tr>
<td>Equipment</td>
<td>Stop Watch or Counting Beads</td>
</tr>
<tr>
<td>Training</td>
<td>OTJ (On The Job)</td>
</tr>
<tr>
<td>Education</td>
<td>Limited</td>
</tr>
<tr>
<td>Validation</td>
<td>None</td>
</tr>
<tr>
<td>Data Collection</td>
<td>None</td>
</tr>
<tr>
<td>Patient Load</td>
<td>Zero – 30 Patients or more per day.</td>
</tr>
<tr>
<td>Access to Clinic</td>
<td>Remote</td>
</tr>
</tbody>
</table>
Pulse Oximetry

Pulse Oximetry measurement has not been demonstrated to be a specific indicator of serious illness, and there is evidence that it lacks specificity. Reduced arterial hemoglobin saturation is common in hospitalized adults, with saturations of between 90% and 95% occurring in up to 37% of patients and saturations of less than 90% occurring in about 11% of patients.

Analysis of Monitors

Spirometer

Several studies have used Spirometry to assess lung function in infants; however, the variables used to quantify the forced expiratory flow volume curves differ among studies, and the relative ability of different variables to discriminate airway obstruction has not been completely evaluated; variability being the key factor.

Analysis of Monitors

Accelerometer

Results show that the estimation of respiratory rate, using a finger pulse oximeter and a chest accelerometer, can be achieved with good accuracy using simply and efficient solutions. The main drawbacks for these algorithms, is that they are not robust against motion artifacts, simply because no precautions for this kind of noises have been implemented.

Embedded Low-Power System for Respiration rate calculation, Universita Degli Studi Di Genova and University College Cork: Microelectronic Department, Canu Allessandro and Canu Massimiliano, A.A. 2009/2010
The Unknown Variable
Finding the Unknown Variable

Subject 1: t1/38 – t2/27 – t3/23
Subject 2: t1/29 – t2/25 – t3/22
Subject 3: t1/27 – t2/23 – t3/20

The respiratory monitor was tested against a test bed that would artificially breath at a fixed rate of 60 breaths a minute, 30 breaths a minute and finally 10 breaths a minute. The accelerometer scored 100% accuracy for all three tests.
Sensing Respiratory Rate

- RIP: (Respiratory Inductance Plethysmography)
- Capacitance Transducer
- Spirometer
- Oximeter
- Accelerometer
Diagnostic Software KST
The IRB was approved for: Valley Health Pediatric Facility

Two Nurses provided the delivery of the breath rate tests.

Fifty children were tested, the mean age 37.08 months, from 1 month to 60 months.
Both well and sick children were enrolled and comments provided for each child tested.

There were 26 males and 24 females,
20 children were visiting their doctor for illness,
30 children were there for a well visit.

During the test the nurses adjudged the children's anxiety rate from calm to upset;
45 children were assessed as not upset.
Method for the Three Tests

The first test was always the nurse touching the child's back by the rib cage to count a breath as the expansion of the rib cage, the number of breaths were noted.

The child was then laid flat on the examination table and a weighted and adhesively applied accelerometer was placed at the thorax area of the child and the button to start the test was pressed.

Within thirty seconds the Z-axes threshold was adjudged as stable and the X and Y-axes algorithm determined the number of diaphragm movements for breath rate. The third test was immediately performed in tandem with the second test. Both breath rate numbers were noted.
### Analysis of Variance

#### Fifty Children

<table>
<thead>
<tr>
<th>Variables</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Children</td>
<td>50.00</td>
</tr>
<tr>
<td>Average age in months</td>
<td>37.08</td>
</tr>
<tr>
<td>Male vs Female Patients</td>
<td>26.24</td>
</tr>
<tr>
<td>Majority of Patients Were Not Upset</td>
<td>00.00</td>
</tr>
<tr>
<td>Level of Significance</td>
<td>P=0.008</td>
</tr>
<tr>
<td>Sick vs Well were equal</td>
<td>50.50</td>
</tr>
<tr>
<td>Both Testers were Female Nurses</td>
<td>1.2</td>
</tr>
</tbody>
</table>

#### Sick or Well

<table>
<thead>
<tr>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.63</td>
<td>12.031</td>
<td>10.035</td>
</tr>
<tr>
<td>29.52</td>
<td>36.28</td>
<td>34.22</td>
</tr>
</tbody>
</table>

P=0.008
Therefore, we have concluded that beyond additional testing, that using a stop watch, beads or touch counting from less than highly trained physicians, caution should be noted that counting breath rate within one minute with a child that is initially presented may exhibit a higher breath rate. Waiting a period of time has limitations, exhibited by “motion artifacts”.

However, it is strongly recommended that only by using an array of sensors or an analog assisted sensory array system for breath rate counting or monitoring under a minute, will a healthcare worker more accurately determine the breath rate of a patient under various environmental conclusions.
Judith Moore, Project HOPE
Sponsors and Participants

- International Rescue Committee
- Project Hope (Founded in 1958)
- UNICEF
- Libelium