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SARA Technology Brief

Technology Engineered to Minimize Nuisance Alarms and Enhance Patient Safety

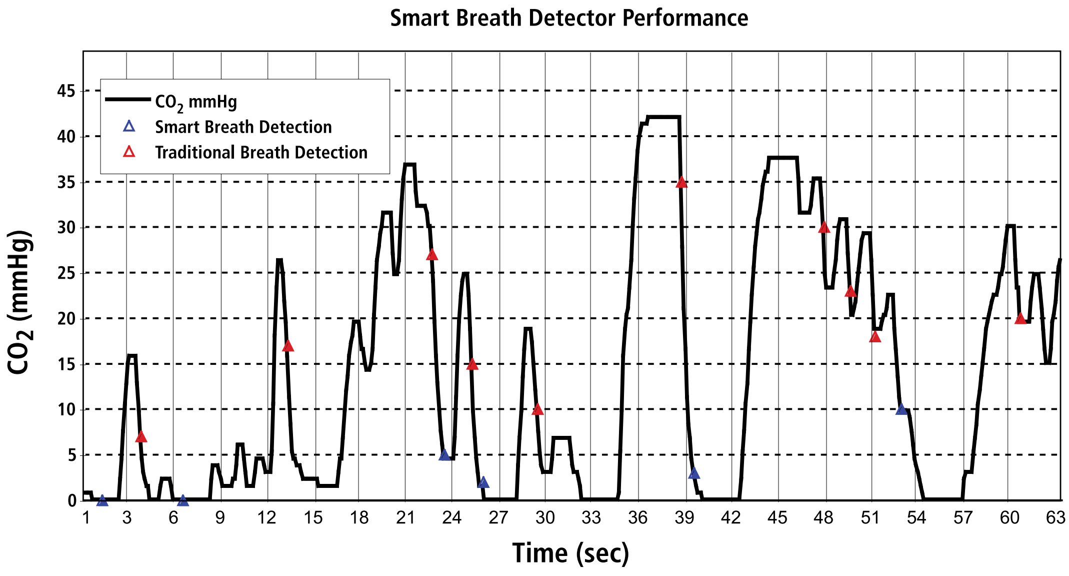
Virtually every patient-connected device uses audible alarms to notify caregivers of a change in patient condition or device status. However, numerous alarms that are not clinically significant are a distraction to busy caregivers. Reducing distractions from clinically insignificant alarms* helps preserve caregiver alarm vigilance, leading to improved patient safety.[1,2]

Smart Capnography™ is a family of algorithms designed to simplify the use of $etCO_2$ monitoring on Microstream®-enabled patient monitors by reducing alarms and providing clinical utility for improved patient safety.[3,4] The key algorithms include the Smart Breath Detection Algorithm™ and the Smart Alarm for Respiratory Analysis™. Together, these two algorithms accurately reflect the patient's condition and help to preserve alarm vigilance.

Smart Breath Detection Algorithm (Smart BDA)

Unlike traditional breath detection algorithms, Smart BDA rejects shallow, non-breath $etCO_2$ excursions (talking, snoring, cardio-genic artifact) from being counted as breaths. The Smart BDA suite of proprietary filter and pattern recognition techniques screens out low-amplitude $etCO_2$ excursions that are superimposed on the $etCO_2$ waveform.

Figure 1: Smart BDA rejects traditional breath detection of shallow $etCO_2$ excursions.



*a clinically insignificant alarm is defined as a respiration rate alarm lasting continuously for less than 30 seconds or less than 45 seconds over a period of 60 seconds when compared to the previous respiration rate algorithm

Smart Alarm for Respiratory Analysis™ (SARA)

The SARA adaptive respiratory-rate-averaging algorithm is an embedded alarm management technology that works with Smart BDA™ to:

- Increase the respiratory-rate-averaging time during periods of high breath-to-breath time period variability; the type of variability seen during periods of talking, snoring, coughing, crying and episodes of pain.
- Reduce the averaging time during periods of low breath-to-breath variability.

Traditionally, two types of methods have been used to monitor respiratory rate. The first type determines respiratory rate by counting the number of breath cycles detected within a fixed time period. The second method measures the time period of detected breaths and updates for every detected breath.

Unlike these methods, SARA employs an adaptive approach. The SARA algorithm evaluates the stability of the detected breath-to-breath intervals and adjusts the measurement period accordingly. During unstable periods, for example when a patient coughs, the averaging time period used for calculating the respiratory rate is increased; during stable periods, the averaging period is decreased. By extending the averaging time period during unstable periods, noise and transient fluctuations are averaged, providing a more realistic respiratory rate. During stable periods free of artifacts, the shorter averaging period increases response time to low respiratory rate events.

To evaluate the variability of the capnogram, SARA uses a Variability Index, which is the standard deviation of the last five breath intervals divided by the mean value of the last five breath intervals. The Variability Index and the respiratory rate are calculated in parallel.

When the clinician begins monitoring a patient, the Capnography Respiratory Rate (RRc) is calculated after every new detected breath by using the average of the last five breath-to-breath intervals.

$$\textbf{Variability Index (VI)} = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}}{\bar{x}}$$

N = the number of breath-to-breath time intervals.
X = breath-to-breath intervals in seconds.
$\bar{X}$ = mean of breath-to-breath intervals.

When the Variability Index goes up, it indicates breath-to-breath variability and possible artifacts. If the Variability Index exceeds a set limit, the number of breaths averaged for the RRc is increased by *n* intervals, where "*n*" is the accumulated number of occurrences where the Variability Index was consecutively greater than the threshold. Conversely, for every breath-to-breath interval where the Variability Index shows stability, *n* is decremented by 1 to a minimum of 5.

VI ↓
- More breath-to-breath interval stability
- Clean data

Action: Decrease number of intervals averaged

VI ↑
- Less breath-to-breath interval stability
- Possible artifact

Action: Increase number of intervals averaged

Clinical Validation for SARA

A study showed that with SARA, respiratory rate (RR) alarms were reduced by 53% overall, and short duration alarms, lasting less than 10 seconds, were reduced by an additional 19%. No significant RR alarms were missed with SARA. See Figure 1 for the comparison of reduction of RR alarms and alarm duration.[5]

When SARA was installed at a hospital in Ohio, the institution reported a substantial reduction in clinically insignificant respiratory rate alarms and fewer Respiratory Therapy clinician complaints.

Summary

SARA automatically adjusts the Capnography Respiratory Rate (RRc) averaging time based on the stability of the measured breath-to-breath intervals, filtering out noise and transient fluctuations. With the SARA adaptive averaging algorithm, the respiratory rate accurately reflects the patient's condition without missing true alarms.

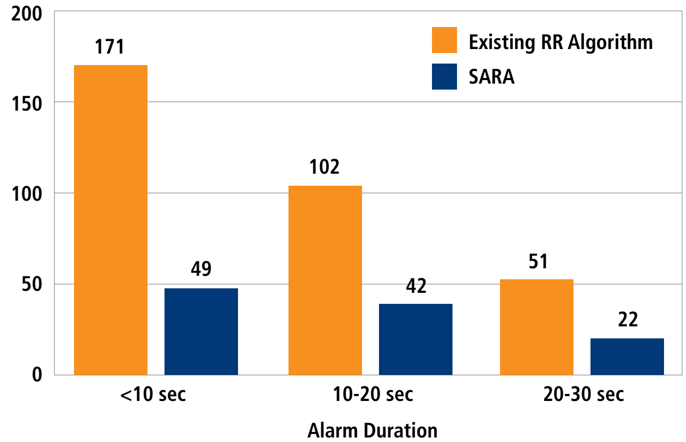


Figure 1: Comparison of alarm events both with and without SARA. Fifty six monitoring periods at 2 hours with the low respiratory rate alarm set at 8 breaths per minute.

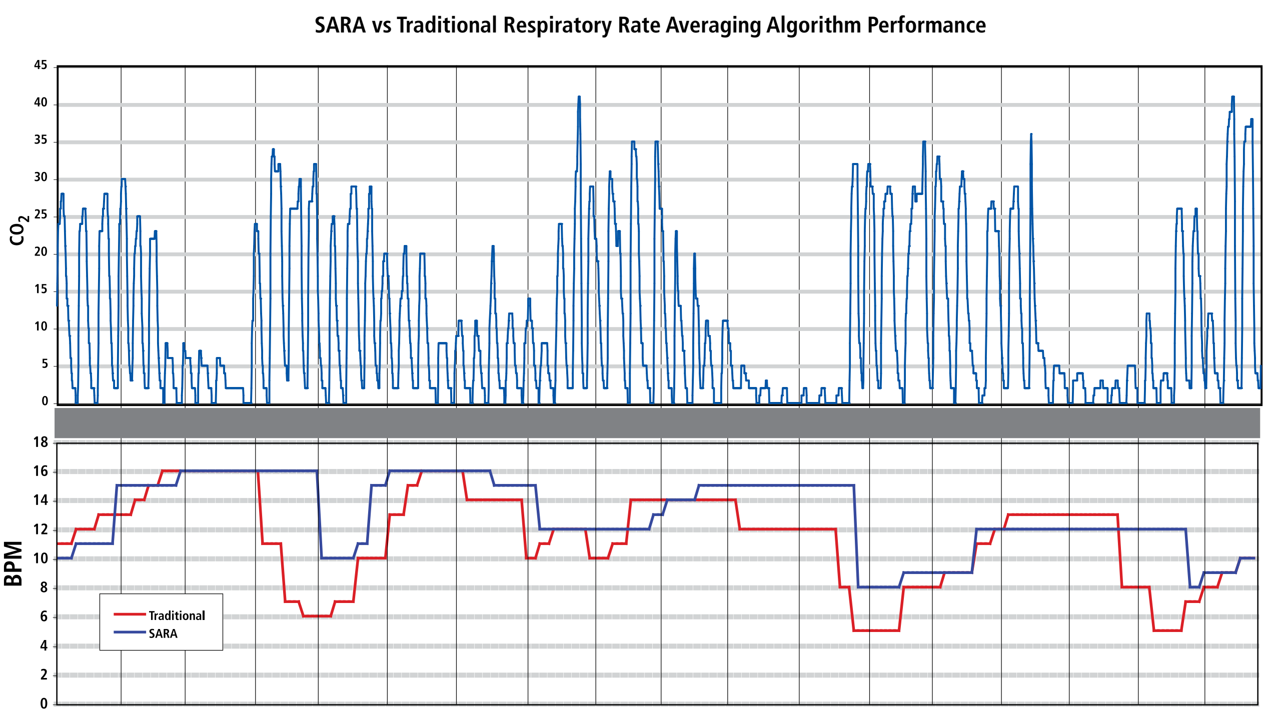


Figure 2: A four-minute capnogram with RRc trends and breath detections, both with and without the SARA and Smart BDA. Note that SARA accurately tracks the patient's true respiratory rate.

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3. Bazin JE. Detection of respiratory depression prior to evidence of hypoxemia in procedural sedation. *Respiratory Care*. 2007;52(11).
4. McCarter TG. End-tidal carbon dioxide monitoring in patient controlled analgesia. *Respiratory Care*. 2007;52(11).
5. Colman J, Cohen J, Lain D. Smart alarm respiratory analysis (SARA) used in capnography to reduce alarms during spontaneous breathing. Supplement to ANESTH ANALG, April 2008, Volume 106, No. 4S, Abstract S-10.

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CDN-R00168-E (MN34912) Rev. 2013/04

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