

THE FUNDAMENTALS OF ...

Apnea Monitors

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Apnea is a Greek word meaning “without wind.” Apnea, in the modern lexicon, refers to the cessation of breathing and is a reversible condition if caught early enough. Apneic events fall under one of three classifications—central, obstructive, or mixed. The event is classified as “central apnea” if the brain stops sending the signals to the chest muscles to expand, causing inhalation. This can occur even when the patient has normal muscle function in the chest. An upper airway obstruction of the airflow is termed “obstructive apnea.” When elements of both are present, it is termed “mixed apnea.”

Prolonged apnea reduces blood and tissue oxygen levels, leading to permanent brain damage and, if not remediated, death. Apnea occurring during otherwise normal sleep is called “sleep apnea” and is suspected to be a factor in Sudden Infant Death Syndrome (SIDS). Because the overall risk factors for apnea are reasonably well defined but the actual onset is unpredictable, apnea monitors provide constant monitoring of those at risk and set off an alarm when apnea is identified.

Current Technology

Apnea monitors basically monitor respirations and usually initiate both visual and audible alarms when the time between breaths, presumed to be an episode of apnea, exceeds a preset time. Many times, there is an integral battery backup to provide continued operation for portability, such as while traveling, and

during power outages. They can be thought of as being comprised of three modules—one that senses breathing, another that determines apneic events, and a third that reports and/or records these events.

Sensing breathing: Because most apnea monitors are used on infants, respiration is often indirectly detected. Indirect detection methods include mattress pressure pads, impedance pneumography, and pneumatic abdominal sensors. Mattress pressure pads detect changes in resistance or capacitance of a mattress transducer. Small pressure changes caused by respiratory motion are interpreted as breaths while large movements are essentially ignored by the electronics.

The popular impedance pneumography method employs basically the same technology used in respiration modules found in intensive care unit (ICU) cardiac monitors. They detect changes in thoracic impedance by passing a low-current high frequency signal through two electrodes placed on either side of the chest. As the infant breathes and the heart pumps blood, the transthoracic impedance changes and these changes are interpreted as breaths. These same electrodes often perform double duty as electrocardiogram (ECG) electrodes to monitor heart activity.

About the Author



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Apnea monitors basically monitor respirations and usually initiate both visual and audible alarms when the time between breaths, presumed to be an episode of apnea, exceeds a preset time.



Apnea is believed to be a factor in Sudden Infant Death Syndrome (SIDS). Apnea monitors are used on infants believed to be susceptible to SIDS.

Apnea monitors determine apneic events by measuring the time between breaths and comparing that to a preset standard.

Pneumatic abdominal sensors are similar to those found in the mattress pressure pad, but are enclosed within a band worn around the abdomen. The sensor detects the expansion and contraction of the abdomen caused by breathing and interprets the pressure changes as breaths.

There are several other designs which utilize direct detection methods that either sample or introduce some form of sensor into the breath stream of the individual being monitored. These methods typically employ temperature, pressure, or carbon dioxide (CO²) sensors. One unusual design monitors tracheal breath sounds.

Two direct methods of sensing apnea involve placing a sensor under the nose or in front of the mouth. Temperature monitors place a thermistor under the nose or in front of the mouth. The thermistor senses the temperature of the air being inhaled or exhaled by the patient—typically cool air on inspiration and warm on expiration. The change or difference in temperature indicates that the patient is still breathing. Pressure monitors work similarly, except that this method measures the small pressure fluctuations at the nostril created by inhaling and exhaling, thus indicating respirations.

Carbon dioxide monitoring for apnea detection works similar to end-tidal CO² monitoring, employing a cannula placed in front of the patient's nose which is connected by small-bore tubing to a small pump that constantly samples gas from the cannula. By constantly sampling the air, typically using an infrared CO² sensor, repetitive variations in CO² levels are indicative of breathing.

Determining an apneic event: No matter the method used, this is fairly straightforward. Apnea monitors determine apneic events by measuring the time between breaths and comparing that to a preset standard. Typically this standard is an adjustable interval as long as 60-seconds between breaths—the range of adjustment varies between brands and models—with the actual setting determined by a healthcare professional. Apnea monitors that use their electrodes to also provide the heart rate typically allow the user to set a lower rate limit to provide an alarm if the heart rate is too slow (bradycardia), probably caused by hypoxia (too little oxygen reaching body tissues and the brain), or too fast (tachycardia). Models that also monitor the ECG use a more complex algorithm which takes both the time between breaths and the slower heart rate into account before indicating the patient has stopped breathing.

High-end units provide a plethora of adjustments, including both upper and lower ECG alarm settings and amplitude adjustments to better differentiate between muscle artifact (noise) and a breath or a heartbeat. These additional adjustments are intended to reduce the incidence of false alarms while allowing the user to precisely determine apneic alarm events.

Reporting/recording apneic events: Although this varies tremendously between models, all low-end units provide both audible and visual alarms. At a minimum, low-end units provide the user with several choices of delay time for determining apnea, and an audible alarm which resets either automatically or manually. On most units featuring self-resetting audible alarms, there is usually a manual reset for the visual alarm indicator so that the light remains illuminated after the audible alarm resets. Better monitors flash a light or make an audible click each time a breath is detected and provide a visual indication (typically a digital readout) of respiration and heart rates.

Some apnea monitors also include optional onboard blood pressure and pulse oximetry to provide complete patient monitoring in a single device. Upper and lower alarm limits can also be set for these vital signs. High-end units often provide external documentation capabilities, such as the ability to “remember” and download several hours of patient event data, especially events leading up to an apneic episode, to a microcomputer using a proprietary software package. This software normally provides tabular or waveform data (frequently both) of monitored parameters; the number, times, and triggering events of alarms; equipment status such as alarm settings; the times at which it was powered on or off; battery condition, etc.

How to Manage the Device

It is strongly recommended that maintenance of apnea monitors be closely tracked, given the litigious nature of today’s society and the fact that these monitors deal with such a vital function, i.e., breathing, and are used on infants believed to be susceptible to SIDS. This means individually, by unique equipment identification or serial number, scheduling of preventive maintenance, functional testing, electrical safety testing, and any calibration required. Additionally, remedial maintenance should be similarly tracked and repairs scrupulously documented.

Regulations

The Food and Drug Administration (FDA) considers apnea monitors to be medical devices and are regulated by them as such. Aside from this FDA regulation, there is no specific regulation of apnea monitors.

Risk Management Issues

Using apnea monitors involves several risk management issues, which can be divided into two general categories. The first category is related to the design of the device itself, while the second is related to its use.

Under the category of design issues, the most important is the possibility the monitor will mistakenly recognize muscle artifact as a breath. If it does this often enough in a minute, it will not sense that the monitored infant is experiencing an apneic episode and delay caregiver response. The second design issue,

similar to mistaking muscle artifact for breathing, is the possibility that other signals, such as electrode vibrations, electronic signals from other devices in the patient vicinity (remember, apneas monitors are often used in the patient’s home) will interfere with breathing detection and be counted as false respirations. Third, depending on the method of sensing breathing the monitor designer chose to use, the basic design may be more prone to misidentifying other events as breathing. For example, impedance pneumography-based designs are more sensitive to cardiovascular artifact than mattress pressure pads or pneumatic abdominal sensor-based designs. This sensing method may mistake gasps for air (caused by spasms or an upper-airway obstruction) to be sighs or large breaths when the patient is actually in distress. Likewise, designs that purposely do not count concurrent inhalations and heartbeats can display low respiration rates and may cause an increase in false apnea alarms.

Risk management issues related to the use of the apnea monitor include irritation to the patient’s skin from the adhesive on the electrodes, users inadvertently disabling the audible alarm, and poor user (parents or caregiver) training on the monitor’s operation and control settings.

Troubleshooting

Designs of basic apnea monitors are fairly well established, so they rarely are the source of failures. More commonly it is the esoteric features of high-end units that are more prone to problems.

Sometimes, users complain that the apnea monitor has too many false alarms, particularly while monitoring an infant susceptible to SIDS, when the patient did not experience an apneic event. The truth of the matter is that there was likely an apneic event and the sound of the audible alarm surprised the infant, causing him or her to gasp and spontaneously resume breathing. If the unit is equipped with an event monitor printer or a way to download patient event data, this scenario will be borne out by the evidence.

Training and Equipment

Biomedical electronics technicians having only basic training can perform scheduled services

Origin and Evolution

Apnea monitors naturally evolved from the monitors used in typical hospital and medical center intensive care units (ICUs). In the late 1960s, solid state technology had evolved to the point where the size and the reduced number of controls and adjustments allowed for more homecare equipment to be developed and fielded. The apnea monitor basically is a specialized respiration/cardiac monitor minus the video scope display, relying instead on a tachometer or other numerical reporting of the monitored parameters. As monitor designs evolved, features such as heart rate detection, automatic sensitivity, and noise-suppressing signal processing algorithms became standard as did the methods for determining apneic events. Although many methods of detecting breathing have been used on legacy units, impedance pneumography is the most widely used method marketed today for both home and hospital unit use.

With most models, no special tools or test equipment are required to service apnea monitors, but maintenance software may be required for more advanced models.

(preventive maintenance, calibration, and electrical safety testing), operational checkouts, and minimal remedial maintenance on apnea monitors. Operation and service manuals are necessary for more advanced remedial maintenance. A safety analyzer and a patient simulator capable of providing both respiration and heartbeat signals are required to perform operational checkouts and remedial maintenance. With most models, no special tools or test equipment are required to service apnea monitors, but maintenance software may be required for more advanced models.

Future Development

Apnea monitors have become increasingly sophisticated since they were originally developed and used in the early 1970s. Since the basic technology is considered mature, future improvements are expected to include the ability to record more information (additional channels) for a longer duration. ■

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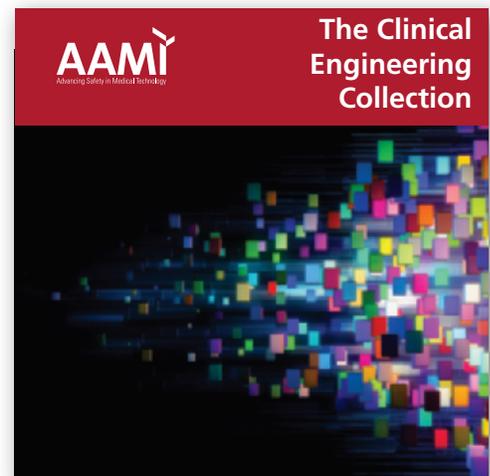
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