The Clinical Value of Infant Monitoring

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Infant Monitoring in the Hospital and Home provides clinical value to healthcare providers. This review is intended for clinicians who may encounter babies who are at risk for Apnea and Apparent Life Threatening Events (aka BRUEs) as well as those who routinely manage these babies through an Apnea Program or Durable Medical Equipment provider. This review focuses on the medical management of Apnea as a symptom of a broad range of possible conditions and the use of event-recording Cardiorespiratory Monitors for monitoring newborns in the hospital and home.

We will cover some background and definitions. We will focus on appropriate set up and use of a Cardiorespiratory Monitor, and how to gather and analyze the data from the monitor. Finally, we will touch on cost considerations of monitoring.

Formal definitions of Apnea, Bradycardia, and Tachycardia are shown in Figure 1:

Central Apnea: Pause in breathing > 20 seconds, or of shorter duration, associated with Bradycardia, Desaturation/Cyanosis/Pallor, Change in neurologic status

Obstructive Apnea: Respiratory effort with loss of air flow,

Mixed Apnea: Combination of Central and Obstructive Apnea

Neonatal bradycardia: Age related Norms
< 38 weeks: 100 bpm
39 - 44 weeks: 80 bpm
45-52 weeks: 70 bpm
53-66 weeks: 60 bpm

Tachycardia: Rhythm Disturbances such as SVT usually present with sustained heart rates much higher than the norms, ranging from 220-320 bpm.

Figure 1. Norms for Cardiorespiratory Events in Infants Apnea

All premature infants are at risk for apnea of prematurity. Apnea is rare among full-term healthy infants and, if present, usually indicates an underlying pathology. Closely associated with apnea of prematurity is periodic breathing. Periodic breathing (PB) is defined as a series of three or more respiratory pauses lasting 3 seconds or longer separated by 20 seconds or more of normal breathing. There are published norms for percentage of periodic breathing, but more importantly are the consequences, such as hypoxia.

Low O2 saturations can be transient or chronic, each with associated risks such as pulmonary hypertension for chronic hypoxia, and developmental delays with frequent hypoxic arousals.

Additional terms that one should be aware of include SUID (Sudden Unexpected Infant Death), ALTE (Apparent Life Threatening Event), and BRUE (brief resolved unexplained event), as explained below.

SUID (Sudden Unexpected Infant Death): The death of an infant younger than 1 year of age that occurs suddenly and unexpectedly. After a full investigation, these deaths may be diagnosed as: Suffocation, Entrapment, Infection, Ingestion, Metabolic diseases, Cardiac arrhythmias, Trauma (accidental or non-accidental); or SIDS. SIDS (Sudden Infant Death Syndrome): One type of SUID, SIDS is the sudden death of an infant younger than 1 year of age that cannot be explained even after a full investigation that includes a complete autopsy, examination of the death scene, and review of the clinical history. Previously used terminology such as "near-miss sudden infant death syndrome" or "aborted crib death" should be abandoned because their use implies a possibly misleading close association between this type of spell and SIDS

ALTE (Apparent Life Threatening Event): An episode that is frightening to the observer and is characterized by some combination of: apnea (central or obstructive); color change (cyanotic, pallid, erythematous or plethoric); change in muscle tone (usually diminished); and choking or gagging.

BRUE: An event occurring in an infant <1 year of age when the observer reports a sudden, brief, and now resolved episode of ≥1 of the following: cyanosis or pallor; absent, decreased, or irregular breathing; marked change in tone (hyper- or hypotonia); altered level of responsiveness. Clinicians should diagnose a BRUE only when there is no explanation for a qualifying event after conducting an appropriate history and physical examination . The terms BRUE and ALTE mean the same type of event, but BRUE can be measured more objectively and should be used rather than ALTE.

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The ED physician may not experience many patients with pure apneic events but more likely will have an infant's caregiver come in and report that his or her child appeared to stop breathing, changed color, or became limp. This is a BRUE.

BRUEs are characterized as Higher-risk or Lower-risk. Lower risk BRUEs meet all of the following criteria:

- age >60 days
- gestational age ≥32 weeks and postconceptional age ≥45 weeks
- occurrence of only 1 BRUE (no prior BRUE ever and not occurring in clusters)
- duration of BRUE <1 minute
- no cardiopulmonary resuscitation by trained medical provider required
- no concerning historical features
- no concerning physical examination findings

Infants who have experienced a BRUE who do not qualify as Lower-risk patients are, by definition, at Higher- risk. Monitoring may be appropriate in Higher-risk infants who have experienced a BRUE. Infants who present in the ED with a Higher-risk BRUE may be discharged with Home Cardiorespiratory Monitoring. Clinicians should not initiate Home Cardiorespiratory Monitoring in infants presenting with a Lower-risk BRUE .

The consequences of Neonatal hypoxia

Apnea of prematurity can lead to death or permanent impairment of mental, psychomotor and functional development as well as cerebral palsy or blindness.

Infants in whom apnea exceeded 20 seconds have an increased incidence of, Intraventricular hemorrhage, Hydrocephalus, Prolonged mechanical ventilation, Abnormal neurologic development after their first year of life.

Infants with clinically significant apnea of prematurity do not perform as well as prematurely born infants without recurrent apneas during neurodevelopmental follow-up testing. The longer the occurrence of apnea of prematurity, the greater the neurodevelopmental impairment as measured by the Bayley scale for mental development and psychomotor development or by the occurrence of cerebral palsy or blindness. The longer the occurrence of apnea of prematurity, the greater the functional impairment as measured by the Vineland scale for Communication, Daily Living Skills, Socialization, and Motor Skills.

Conditions to Monitor

Apnea of prematurity is the most common problem in premature neonates. The earlier a baby is born before full term, the higher their likelihood of having apnea of prematurity.

Cardiorespiratory monitoring improves bedside detection of apnea of prematurity. Clinicians heavily rely on nursing documentation to make decisions. Yet published findings show that even highly trained observers miss more than 50% of apnea of prematurity episodes. At the same time, standard hospital monitors do not tell the whole story. They make continuous recordings, events are not easy to locate in the records and alarms are often ignored by hospital staff. Apnea, bradycardia, and desaturation events are subjective in nature unless the standard definition is strictly followed. Event recording Cardiorespiratory Monitors allow these standards to be strictly followed and provide alarms when pre-set limits are exceeded. Precise diagnosis of apnea of prematurity requires multichannel recordings, which are most commonly measurements of thoracic impedance, heart rate, and O_2 saturation. Expanded testing may include air flow, electroencephalography and/or use of an esophageal pH probe. Accurate documentation of "spells" prior to discharge can aid in decision making.

Figure 2. Smart Monitor 2 from Circadiance Event-recording Cardiorespiratory Monitor.

Babies are assessed prior to discharge in NICU or transitional space (step down nursery). Patients in step down units are commonly monitored with a Home Cardiorespiratory Monitor as central Cardiorespiratory Monitors found in the NICU may not be available.

Apnea of prematurity may not resolve at term and may persist for some time after hospital discharge. These babies should be considered for home monitoring if Apneas or Bradycardias persist as discharge date nears. Following recommendations by the American Academy of Pediatrics, these symptomatic preterm infants should be considered for monitoring in the home.

Home Monitoring allows management of infants discharged on caffeine citrate therapy. These infants are rarely sent home without a monitor as apnea may reoccur as the baby outgrows their therapeutic caffeine level. Without a monitor the caregiver may not recognize when apneas reappear. Cardiorespiratory monitoring after hospital discharge may be prescribed for some preterm infants with an unusually prolonged course of recurrent, extreme apnea.

Home Monitoring enables healthcare providers to manage outpatients with conditions that may affect breathing, Heart Rate or O2 saturation. Figure 3 demonstrates the quality of the graphical data recorded when an event occurs.

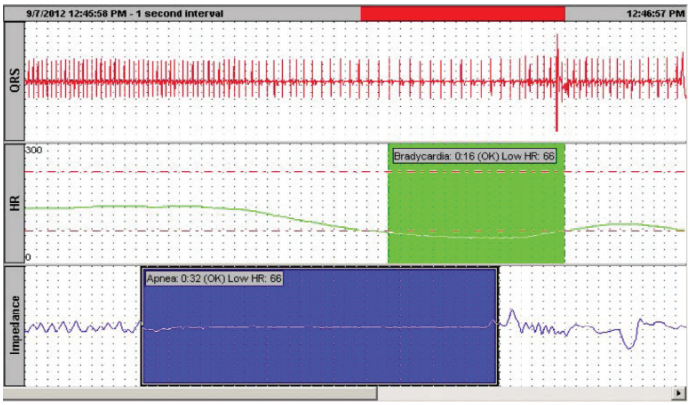

Figure 3. High quality waveforms enables diagnosis and management of conditions that may affect breathing, Heart Rate or O2 saturation.

Event recording monitors enable healthcare providers to manage infants who may have subtle or intermittent problems such as cardiac conditions, seizures, parental neglect or abuse, or the onset of infections.

Infants who have experienced a Higher-risk BRUE may be appropriate candidates for home monitoring. Clinicians should not initiate Home Cardiorespiratory Monitoring in infants presenting with a Lower-risk BRUE.

Home Monitoring may be appropriate for discharged babies who have displayed cardiac abnormalities such as: Supraventricular Tachycardia, Ectopic atrial tachycardia, Atrial flutter, First - , second - , and third -degree heart block, Wolff - Parkinson - White Syndrome.

Home Monitoring may provide evidence to establish parental abuse or neglect, Munchausen Syndrome by Proxy or seizures. Many infants will present with a sudden increase in apnea alarms 12 to 24 hours before becoming clinically symptomatic with respiratory syncytial virus (RSV) or sepsis.

For caregivers of a subsequent child born after a sibling died from SIDS, monitoring may relieve anxiety related to fear of a second event, even when counseled about limitations of monitoring. This compassionate use of Home Cardiorespiratory Monitors may or may not be covered by the patient's insurance.

There are a variety of conditions to not use Cardiorespiratory Monitors. Cardiorespiratory Monitors are not recommended as a strategy to prevent SIDS. Commercial devices that are designed to monitor infant vital signs do not reduce the risk of SIDS. The American Academy of Pediatrics specifically recommends against using consumer oximeter devices that have not been cleared by the FDA.

Equally as important as criteria to initiate home monitoring are those to discontinue the monitor. Current evidence suggests that if such monitoring is elected, it can be discontinued in most infants:

- After 43 weeks' PMA unless indicated by other significant medical conditions
- Usually monitored for 4-6 weeks after cessation of events
- Off caffeine, oxygen, and occasionally, diuretics
- Caregiver comfortable with discontinuation

Figure 5. The Car Seat Challenge which is recommended by the American Academy of Pediatrics when discharging any newborn at less than 37 weeks gestational age or who was low birth weight even at full term.

Consideration for home monitoring is often a part of discharge planning. Usually, there are three conditions to be met for discharge of a preterm neonate:

- Oral feeding sufficient to support appropriate growth
- Ability to maintain normal body temperature in a home environment
- Sufficiently mature respiratory control

There is no consensus as to the apnea-free interval before discharge. In general:

- Babies should be apnea-free for 5-7 days before discharge. The interval is not clearly established, and some NICUs require longer intervals.
- Reducing this time facilitates earlier discharge, especially if monitors are available for home use.

Another consideration for discharge is the Car Seat Challenge. It is important because premature infants who are discharged from intensive care nurseries are known to be at increased risk for apnea, bradycardia, and oxygen desaturation while in the upright position. Car Seat Challenge is a period of monitoring in the infants own car seat to verify cardiac and respiratory stability while seated in the upright position. The test usually lasts for 90-120 minutes or the duration of the car ride home, whichever is longer. Data can be downloaded from the monitor for clinicians to evaluate when making discharge planning decisions. This

Recommended	Not recommended
• When Apnea of prematurity unresolved by discharge date • As part of discharge planning • Enables doctors to manage discharged infants with conditions that may affect breathing, Heart Rate or O2 saturation • Enables doctors to manage discharged infants who may have subtle or intermittent problems like cardiac conditions, seizures, parental neglect or abuse, or the onset of infections. • When babies present in the ED with Higher Risk BRUEs	• In full term healthy infants • When Apnea of prematurity resolved by discharge date • When babies present in the ED with Lower Risk BRUEs • As a strategy to prevent SIDS. • Commercial baby monitors, not cleared by the FDA, should not be used

Figure 4. Appropriate use of Cardiorespiratory Monitors. These recommendations are consistent with the guidelines provided by The American Academy of Pediatrics.

data can be included in patient medical record. The Car Seat Challenge which is recommended by the American Academy of Pediatrics when discharging any newborn at less than 37 weeks gestational age or who was low birth weight even at full term. The Car Seat Challenge is a billable procedure.

Earlier discharge from the ICU allows the pre-term baby to go home, which provides better quality of life for the baby and for the family, as well as lowers the cost of care and improves profitability for the hospital.

Home Monitoring

The home care provider should set up monitor in the NICU prior to discharge to enable the family to become familiar with the equipment and the alarms. Parents "room in" with their baby the last night in the hospital. Those caring for an infant with apnea of prematurity should be trained in CPR. This training in the NICU reduces caregiver anxiety and allows them to participate in the care of their infant. It reduces the number of calls to the home care provider office. Proper training reduces likelihood of broken equipment. And it helps achieve compliance.

One of the frequent complaints about home monitoring is the number of alarms. Alarms may be related to the condition of the baby, which are relevant to the babies care. They may also be related to the equipment which are considered clinically irrelevant alarms**.** Proper placement of leads will minimize alarms. Ensure electrodes are placed along the mid-line of the side; two finger widths below or lined up with the nipples.

Figure 6. Proper lead placement helps reduce clinically irrelevant alarms.

If a good signal is not achieved, observe the patient's breathing and reposition electrodes in the location of greatest chest excursion. Remind parent's to ensure that the baby's skin is dry and clean and free of lotions and oils. If using an electrode belt, remove it for an hour a day. Clean reusable electrodes daily. Add a drop of water on skin under carbon electrode to help improve conductivity.

Documentation

The event-recording Cardiorespiratory Monitor will provide important documentation including multi-parameter recording of ECG, heart rate, respiration, SpO2 when an alarm or record setting is violated. An event-recording Cardiorespiratory Monitor provides near diagnostic quality ECG waveform to aid in the diagnosis and treatment of cardiac arrhythmias and respiratory anomalies, as was previously shown in figure 3. It also provides a complete record of events which helps document monitor usage and compliance, as clearly shown in the Figure 7.

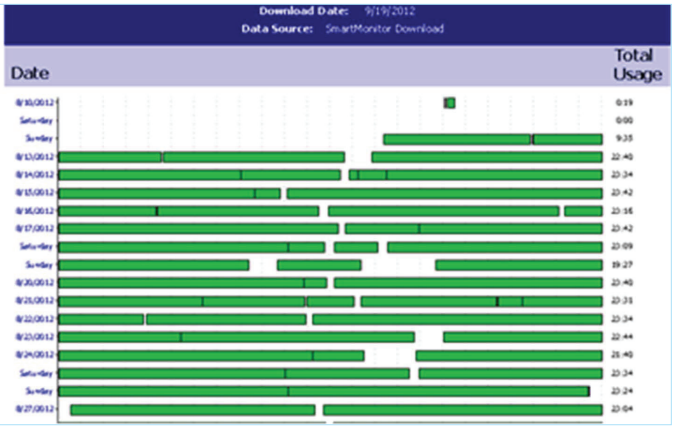

Figure 7. A compliance report provides a graphical record of when the infant was monitored.

Cost Considerations of Home Monitoring

If used correctly, Home Cardiorespiratory Monitors can save money. There is no standardization as to how long to keep premature infants in the NICU but many nurseries will put infants that are otherwise ready to be discharged (taking feedings well, able to maintain their temperature, and growing) on a 5-7 day "apnea/bradycardia" watch. That is, they keep the child in the NICU for 5-7 days after the last documented episode of apnea/bradycardia. However, earlier discharge from the NICU even within 3-4 days event-free and then sending home on a monitor for 1-2 months is much more cost effective.

One study resulted in out-patient management cost savings per eligible patient ranging from $2,422 to $62. Sensitivity analysis demonstrated few instances of decreased relative cost-effectiveness.

At my hospital, in the early 90s, we instituted a neonatal clinical pathway that promoted more rapid achievement of full feeds. When babies met this criteria, along with ability to maintain body temperature in an open crib, and not having significant cardiorespiratory events requiring aggressive intervention, they were discharged home on event-recording Cardiorespiratory Monitors. After 6 months of pathway introduction, we had reduced ALOS by 7.5 days, and average costs by $19,400 per patient. This has become our standard of care and culture in the NICU.

Benefits of Cardiorespiratory Monitoring

Cardiorespiratory monitoring Improves bedside detection and assists in precise diagnosis of apnea of prematurity in the hospital. It enables the potential for earlier hospital discharge of premature infants. Earlier discharge provides better quality of life for the baby and for the family, as well as lowers cost of care and improves profitability for the hospital. Cardiorespiratory monitoring enables health care providers to manage discharged infants with conditions that may affect breathing, Heart Rate or O2 saturation or who may have subtle or intermittent problems like cardiac conditions, seizures, parental neglect or abuse, or the onset of infections. Home Monitor alarms allow the parents to quickly respond in the event a pre-term baby stops breathing or has a bradycardia, and to have better peace of mind as the baby outgrows the need to be monitored. Cardiorespiratory monitoring provides documentation of the condition and management of at-risk infants throughout their hospital stay and subsequent treatment received in the home early in life.

Conclusion

Cardiorespiratory monitoring is clinically useful, technologically relevant, and economical. Monitoring enables the diagnosis and management of at-risk vulnerable infants to provide better outcomes. Monitoring improves the quality of life for a pre-term infant by enabling the baby to go home earlier, and peace of mind for their family, knowing that their baby will not suffer from undetected life threatening events. Monitoring lowers cost of care by providing a low cost alternative to hospital care, enabling earlier NICU discharge.

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