Published in final edited form as:

Am J Perinatol. 2013 September ; 30(8): 643–648. doi:10.1055/s-0032-1329694.

Monitoring Apnea of Prematurity: Validity of Nursing Documentation and Bedside Cardiorespiratory Monitor

Sanjiv B. Amin, MD, MS¹ and Erica Burnell, RN¹

¹Division of Neonatology, Department of Pediatrics, University of Rochester Medical Center, Rochester, New York

Abstract

Objective—To compare apnea events recorded by bedside cardiorespiratory monitor and nursing documentation with those detected by visual inspection of continuous electronic cardiorespiratory waveform.

Methods—In a prospective observational study, 20 nonventilated infants of 28 to 33 weeks' gestational age were monitored for apnea during the first 2 postnatal weeks. Apnea was defined as a respiratory pause > 20 seconds or > 15 seconds if associated with a heart rate < 80/min or oxygen saturation < 85%. True apnea was defined as one for which visual inspection of continuous electronic cardiorespiratory waveform on the central monitor verified apnea.

Results—The number of apnea episodes recorded by nursing documentation and bedside monitors were 207 and 418, respectively. Only 7.7% of apnea events recorded by nursing documentation were confirmed as true apnea compared with 50.4% of apnea recorded by bedside monitors and the difference was statistically significant. Of true apnea ($n = 211$) episodes recorded on central monitors, 99% were recorded by bedside monitors but only 7.6% of apnea occurrences were recorded by nursing personnel.

Conclusions—Nursing documentation does not provide accurate monitoring of apnea. Although bedside monitors have better sensitivity and specificity than nursing documentation, future research should be directed to improve the specificity of bedside monitoring.

Keywords

neonatal intensive care unit; bradycardia; desaturation; premature infants

Apnea of prematurity, defined as cessation of breathing for > 20 seconds, is extremely common among premature infants born < 34 weeks' gestational age.^{1,2} The underlying mechanism for apnea of prematurity is thought to be immaturity of respiratory control with incidence inversely proportional to gestational age and chronologic age.^{1–3} Therefore, it is a routine practice to continuously monitor premature infants' < 34 weeks' gestational age for

apnea of prematurity with bedside cardiorespiratory monitors until the resolution of apnea of prematurity.

The bedside cardiorespiratory monitor uses impedance technology and detects respiration by translating changes in electrical properties of the thorax into a waveform that represents breathing.⁴ Bedside monitors also provide continuous heart rate monitoring using impedance technology and also display oxygen saturations measured using pulse oximetry.⁴ Bedside nurses usually document apnea in the medical records after visual evaluation of the infant when an apnea alarm is triggered, and this documentation is routinely used by neonatologist for the evaluation and management of central apnea including initiation, maintenance, and discontinuation of xanthine therapy and respiratory support. These observations are also commonly used to evaluate the apnea-free period of 5 to 10 days before ceasing apnea monitoring at the time of discharge to home.⁵

Previous studies have shown that nursing documentation of apnea is inaccurate when compared with documented event monitoring using event-recorder monitors that allow visual inspection and analysis of electronic cardiorespiratory waveform.⁶ Similarly, it has been shown that infant monitor alarms are not accurate when compared with documented event monitoring using event-recorder monitors for home monitoring.^{7,8} However, nursing documentation of apnea has not been prospectively evaluated and compared with bedside infant monitors over an extended period in individual premature infants in the neonatal intensive care unit (NICU) using objective assessment of apnea by visual inspection and analysis of continuous electronic cardiorespiratory waveform. Like the event-recorder monitor, a central monitor (Clinical Information Center, GE Medical Systems, General Electric Company, Milwaukee, WI), which may be available in some NICUs, uses impedance technology and provides documented event monitoring. It provides assessment of true apnea by visual inspection of electronic cardiorespiratory waveform, which is recorded in real time and stored in memory for 72 hours. We hypothesize that nursing documentation and bedside cardiorespiratory monitors do not provide accurate monitoring of true apnea when compared with visual inspection of continuous electronic cardiorespiratory waveform. Our objective was to evaluate the validity of bedside monitoring and nursing documentation of apnea events by comparing apnea events recorded by bedside cardiorespiratory monitor and by nursing documentation with those detected by visual inspection of continuous electronic waveform on central monitors over a 2-week period in premature infants. The study was approved by the local Institutional Research Board and parental consent was obtained for each subject.

Methods

Study Design and Population

A prospective observational study was performed involving premature infants 28 to 33 weeks' gestational age delivered at the University of Rochester Medical Center and enrolled in a National Institute of Health-funded study to evaluate jaundice-associated central apnea. Our exclusion criteria were: (1) infants who required mechanical ventilation; (2) infants who required continuous positive airway pressure with intermittent ventilator rate; (3) infants with toxoplasmosis, rubella, cytomegalovirus, syphilis, herpes, or human immunodeficiency

viral infection; (4) infants with craniofacial malformations; and (5) infants with chromosomal abnormalities.

Apnea Monitoring

Nonventilated premature infants were prospectively evaluated for the number of apnea events in the first 2 postnatal weeks using nursing documentation, bedside cardiorespiratory monitors, and visual inspection and analysis of continuous electronic waveform using central monitors (GE Medical Systems).

As part of the standard of care, all premature infants admitted to the NICU are monitored for central apnea using a cardiorespiratory event-recording monitor at the bedside. Each infant has three electrode leads connected to bedside monitors from which electrocardiograph and chest impedance signals are generated. The monitors compute the heart rate every 2 seconds by averaging the RR intervals of the preceding eight beats and the respiratory rate by counting the impedance oscillations. In addition, all premature infants are monitored for desaturations using continuous pulse oximetry. For the purpose of the study, bedside cardiorespiratory monitors and central monitors were programmed to record and alarm all respiratory pauses lasting > 15 seconds, heart rate declines to < 100 beats per minute, and oxygen saturations < 85% in study subjects. The information stored in the bedside monitor including apnea, time of occurrence of apnea, duration of apnea, and associated desaturation and bradycardia were printed out every 12 hours in individual subjects for the first 2 weeks after birth. Similarly, the events recorded on central monitors were printed out daily for the first 2 weeks in each individual subject and verified by visual inspection of continuous cardiorespiratory waveform. In addition, the entire tracing of cardiorespiratory waveform was visually inspected for the duration of the study. The nursing documentation as part of standard of care included apnea, time of occurrence of apnea, associated color change and/or oxygen desaturation, associated bradycardia, and need for intervention (e.g., tactile stimulation, supplemental oxygen, or bag and mask ventilation). Nursing documentation of apnea, time of occurrence, and associated desaturation and/or bradycardia in the medical record was collected daily from the bedside medical charts of individual subjects.

Each of the apnea events recorded on bedside cardiorespiratory monitors were then visually inspected and analyzed by an investigator using the continuous electronic waveform tracings on central monitors within 2 minutes of the documented event on the bedside monitor. Similarly, nursing documentation of apnea events were also reviewed by an investigator using the visual inspection of continuous electronic waveform on the central monitor 15 minutes before and after the documented event by the nursing personnel.

Apnea Definition

For the purpose of the study, apnea was defined as a respiratory pause > 20 seconds or a respiratory pause of 15 seconds or greater if associated with a heart rate < 80/min or oxygen saturation < 85%. True apnea was defined as one for which visual inspection and analysis of continuous electronic cardiorespiratory and oxygenation waveform on the central monitor verified central apnea. Apnea was considered to be accurately detected by nursing documentation if it had been documented within 15 minutes of an apnea observed on central

monitor using visual inspection of continuous electronic waveform. Apnea was considered to be accurately detected by bedside monitors if it had been documented within 2 minutes of the apnea observed on central monitor using visual inspection of continuous electronic waveform. Apnea identification was considered false-positive by nursing documentation if it was recorded in nursing documentation but not verified within 15 minutes of nursing documentation on central monitors. Similarly, apnea identification was considered false-positive by bedside monitors if it was recorded on bedside monitors but not verified on central monitors within 2 minutes of recorded time on bedside monitors. Apnea identification was considered failed (false-negative) by nursing documentation if it was not documented by the nursing personnel within 15 minutes of its occurrence as observed on visual inspection of continuous electronic waveform. Similarly, apnea identification was considered failed by bedside monitors if it was not recorded within 2 minutes of its occurrence as observed on visual inspection of continuous electronic waveform. The nursing staff was made aware of the study before the initiation of the study but the specific objectives of the study were not disclosed. Infants received evaluation and therapy for apnea at the discretion of the attending neonatologist.

Statistical Analyses

Chi-square analysis was used to compare proportion of apnea identified as true apnea between nursing documentation and bedside cardiorespiratory monitors. Similarly, chi-square analysis was used to compare proportion of true apnea missed by nursing documentation and bedside cardiorespiratory monitors. Differences were considered significant at the level of $p < 0.05$.

Results

Thirty infants were enrolled in the study, of whom 10 (seven on ventilator and three on ventilator rate with continuous positive airway pressure) were excluded within the first 2 days after birth. Twenty infants of 28 to 33 weeks' gestational age met study criteria and were evaluated for the first 2 postnatal weeks after birth. The mean gestational age of infants was 30.5 weeks (range 28 to 33 weeks). The mean birth weight of infants was 1335 g (range 1109 to 1760 g). Twelve infants were male. Sixteen infants (80%) received methylxanthine therapy for the treatment of apnea of prematurity during the study period.

There were a total of 207 apneas recorded by nursing documentation among 20 infants over the 2-week period. For most apnea, the duration and type were not recorded in nursing documentation and therefore apnea events were not further categorized by duration or type of apnea and were presumed to be central apnea. A total of 418 apnea events were recorded by the bedside cardiorespiratory monitors among 20 infants over the same 2-week period. There were 211 apnea occurrences recorded by central monitors among 20 infants over the 2-week period. Of these 211 events, 63 events were respiratory pauses > 20 seconds and the remaining were respiratory pauses of 16 to 20 seconds but associated with either bradycardia or desaturation.

Of the apnea recorded by nursing documentation, 7.7% ($n = 16$) of apnea events on nursing documentation were confirmed as true apnea by visual inspection of continuous

cardiorespiratory waveform. The 20% ($n = 38$) of the remaining apnea episodes documented by nurses, however, were associated with respiratory pauses of ≥ 15 seconds and bradycardia and/or desaturation on central monitors. The remaining false-positive apnea episodes documented by nurses were associated with artifact or bradycardia or desaturation. Of the apnea recorded by bedside monitors, 50.4% ($n = 211$) of apnea events were confirmed as true apnea by central monitors and the remainder were false-positive associated with either short respiratory pauses or artifacts. On comparing nursing documentation with bedside monitoring, bedside monitoring was associated with a higher specificity compared with nursing documentation (50.4% versus 7.7%, $p < 0.01$).

Among events recorded and confirmed to be true central apnea on central monitors, 99% ($n = 209$) of true events were recorded by bedside cardiorespiratory monitors indicating high sensitivity of bedside monitors but only 7.6% ($n = 16$) of true events were recorded by nursing personnel indicating low sensitivity of nursing documentation. The difference in sensitivity between bedside monitors and nursing documentation was significantly different ($p < 0.01$). Among true apnea episodes not documented by nursing personnel, 14.6% were respiratory pauses of > 20 seconds that were not associated with either bradycardia or desaturation.

Discussion

Premature infants < 34 weeks' gestational age are routinely monitored for apnea of prematurity. Neonatologists primarily rely on nursing documentation of apnea for the evaluation and management of apnea in prematurity. The bedside cardiorespiratory monitor that usually stores cardiorespiratory events up to 24 hours is often used by neonatologist for gathering additional information on apnea, specifically the duration of apnea and whether apnea was associated with bradycardia and/or desaturation. Similarly, researchers have routinely used nursing documentation of apnea and bedside monitors for assessment of apnea in clinical studies involving apnea as the primary study measure.^{2,9-13} Our findings suggest that neither nursing documentation of apnea nor bedside cardiorespiratory monitors provide accurate monitoring of apnea when compared with visual inspection and analysis of continuous electronic cardiorespiratory waveform.

Immediate identification of apnea of prematurity is essential for timely intervention and preventing respiratory arrest. Recurrent apnea has also been associated with abnormal neurodevelopmental outcome and therefore methylxanthine such as caffeine is commonly used to prevent and treat apnea during the NICU stay.¹⁴⁻¹⁶ Furthermore, unusual frequent occurrence of apnea in a premature infant is often an early manifestation of sepsis and usually triggers a sepsis evaluation and antibiotic therapy. For these clinical reasons, accurate monitoring of apnea is critically important. Consideration of a false apnea event as real by clinicians may lead to unnecessary and costly evaluation and therapy. On the contrary, if true apnea events are not identified, it may delay timely evaluation for underlying cause and or early discontinuation of medications. In addition, accurate monitoring of apnea is essential in premature infants for earlier and safe discharge to home. An apnea-free period of 5 to 10 days off methylxanthine therapy is considered indicative of

maturity and a low risk for recurrent apnea among premature infants and is commonly used as a criterion before considering a safe discharge to home.⁵

Our findings suggest that there is significant discrepancy in records of apnea between nursing documentation and central monitors; specifically, the majority of apnea events recorded over a 2-week period by the nursing personnel in individual subjects were not true apnea when evaluated by visual inspection of continuous electronic waveform. Our findings are in agreement to the findings of Razi et al, who reported that only 20% of nursing-documented apnea events were verified by visual inspection of transthoracic impedance.⁶ One explanation for this discrepancy is that nurses are likely to record short respiratory pauses as apnea if associated with bradycardia and/or desaturation. This is suggested by our finding that 20% of apnea episodes recorded by nursing personnel were noted on central monitors to be short respiratory pauses (<15 seconds) associated with either bradycardia or desaturation. Previous studies have also reported that bradycardia and desaturation in premature infants are commonly preceded by short respiratory pauses.¹⁷ Another explanation for this discrepancy may be that nurses record both obstructive and central apnea but the impedance technology captures only central apnea. In a study comparing nursing documentation with apnea identified by a computer programmed to identify both central and obstructive apnea, there was less discrepancy noted between nursing documentation and computer-identified apnea with nurses documenting 54% of computer-identified true apnea.¹⁸ However, for clinical purpose, premature infants are rarely monitored in the NICU for obstructive apnea using an appropriate respiratory monitoring device.⁴

We also found that the majority of significant central apnea events observed on central monitors were not detected and documented by the nursing personnel. Our finding that nursing records do not provide accurate documentation of apnea of prematurity is consistent with previously reported findings of Razi et al,⁶ who reported that 62% of apnea episodes recorded on documented event monitoring were not documented by nursing personnel.⁶ One plausible explanation is the impracticality of visual inspection of the infant for confirmation of apnea with each monitor alarms. In most NICUs, one nurse is often responsible for the care of more than one premature infant. Therefore, nurses may not be able to respond immediately to bedside alarms and visually evaluate the infant and confirm the apnea. It is possible that the apnea event may have resolved by the time nursing personnel visually evaluate the infant, obviating the need for documentation.

Our finding that false apnea alarms or records are frequent on bedside monitors is consistent with the findings reported by others using event-recorder monitors.⁸ However, on comparing with nursing documentation, we found that bedside monitors have significantly higher specificity than nursing documentation. Our findings underscore the importance of validating the event recorded on bedside cardiorespiratory monitors or in nursing documentation by visual inspection of continuous electronic cardiorespiratory waveform. This may be extremely useful and important while monitoring for an apnea-free period of 5 to 10 days before safe discharge to home, a common practice in several NICUs.⁵ During an era when there is increasing financial pressure for early discharge, a validation using visual inspection of cardiorespiratory waveform on central monitors that the apnea documented by

nursing or bedside monitors is not a true apnea event may help decrease the hospital stay and related cost.¹⁹

The major limitation of this study is that bedside and central monitors were not programmed to monitor obstructive apnea. The strength of the study is prospective evaluation of apnea over an extended period in each individual subject allowing representation of most of the nursing staff working in a busy level III NICU. Our findings provide additional evidence that nursing documentation does not provide accurate monitoring of central apnea. This raises concerns about use of nursing documentation in decision making for the evaluation and management of apnea. Although bedside cardiorespiratory monitors provide better apnea monitoring than nursing documentation, future research is urgently needed to improve the existing technology so as to improve the accuracy of apnea monitoring. The visual inspection of continuous cardiorespiratory waveform on central monitor provides an alternative mode of apnea monitoring and could be particularly useful for validating apnea during monitoring for apnea-free period, allowing discontinuation of monitoring at an earlier period, and providing reassurance to the parents. Future studies on apnea should also avoid use of nursing documentation of apnea but rather consider use of central monitor or equivalent documented event monitoring to provide content validity.

Acknowledgments

The research was supported by NIH K-23 DC 006229 grant. The authors would like to thank Hongyue Wang, PhD, for biostatistical support.

References

1. Miller MJ, Martin RJ. Apnea of prematurity. *Clin Perinatol*. 1992; 19:789–808. [PubMed: 1464191]
2. Eichenwald EC, Aina A, Stark AR. Apnea frequently persists beyond term gestation in infants delivered at 24 to 28 weeks. *Pediatrics*. 1997; 100(3 Pt 1):354–359. [PubMed: 9282705]
3. Baird TM. Clinical correlates, natural history and outcome of neonatal apnoea. *Semin Neonatol*. 2004; 9:205–211. [PubMed: 15050213]
4. Di Fiore JM. Neonatal cardiorespiratory monitoring techniques. *Semin Neonatol*. 2004; 9:195–203. [PubMed: 15050212]
5. Darnall RA, Kattwinkel J, Nattie C, Robinson M. Margin of safety for discharge after apnea in preterm infants. *Pediatrics*. 1997; 100:795–801. [PubMed: 9346978]
6. Razi NM, Humphreys J, Pandit PB, Stahl GE. PredischARGE monitoring of preterm infants. *Pediatr Pulmonol*. 1999; 27:113–116. [PubMed: 10088934]
7. Nathanson I, O'Donnell J, Commins MF. Cardiorespiratory patterns during alarms in infants using apnea/bradycardia monitors. *Am J Dis Child*. 1989; 143:476–480. [PubMed: 2929530]
8. Weese-Mayer DE, Brouillette RT, Morrow AS, Conway LP, Klemka-Walden LM, Hunt CE. Assessing validity of infant monitor alarms with event recording. *J Pediatr*. 1989; 115(5 Pt 1):702–708. [PubMed: 2681636]
9. Bell EF, Strauss RG, Widness JA, et al. Randomized trial of liberal versus restrictive guidelines for red blood cell transfusion in preterm infants. *Pediatrics*. 2005; 115:1685–1691. [PubMed: 15930233]
10. Mitchell AJ, Green A, Jeffs DA, Roberson PK. Physiologic effects of retinopathy of prematurity screening examinations. *Adv Neonatal Care*. 2011; 11:291–297. [PubMed: 22123352]
11. Murphy JJ, Swanson T, Ansermino M, Milner R. The frequency of apneas in premature infants after inguinal hernia repair: do they need overnight monitoring in the intensive care unit? *J Pediatr Surg*. 2008; 43:865–868. [PubMed: 18485955]

12. Carbone T, McEntire B, Kissin D, et al. Absence of an increase in cardiorespiratory events after diphtheria-tetanus-acellular pertussis immunization in preterm infants: a randomized, multicenter study. *Pediatrics*. 2008; 121:e1085–e1090. [PubMed: 18450851]
13. Amin SB, Charafeddine L, Guillet R. Transient bilirubin encephalopathy and apnea of prematurity in 28 to 32 weeks gestational age infants. *J Perinatol*. 2005; 25:386–390. [PubMed: 15843815]
14. Janvier A, Khairy M, Kokkoti A, Cormier C, Messmer D, Barrington KJ. Apnea is associated with neurodevelopmental impairment in very low birth weight infants. *J Perinatol*. 2004; 24:763–768. [PubMed: 15329741]
15. Taylor HG, Klein N, Schatschneider C, Hack M. Predictors of early school age outcomes in very low birth weight children. *J Dev Behav Pediatr*. 1998; 19:235–243. [PubMed: 9717132]
16. Cheung PY, Barrington KJ, Finer NN, Robertson CM. Early childhood neurodevelopment in very low birth weight infants with predischage apnea. *Pediatr Pulmonol*. 1999; 27:14–20. [PubMed: 10023786]
17. Di Fiore JM, Arko MK, Miller MJ, et al. Cardiorespiratory events in preterm infants referred for apnea monitoring studies. *Pediatrics*. 2001; 108:1304–1308. [PubMed: 11731652]
18. Muttitt SC, Finer NN, Tierney AJ, Rossmann J. Neonatal apnea: diagnosis by nurse versus computer. *Pediatrics*. 1988; 82:713–720. [PubMed: 3186350]
19. Zupancic JA, Richardson DK, O'Brien BJ, Eichenwald EC, Weinstein MC. Cost-effectiveness analysis of predischage monitoring for apnea of prematurity. *Pediatrics*. 2003; 111:146–152. [PubMed: 12509568]