



Abstract

Background: The sudden collapse of an apparently healthy newborn, or sudden unexpected postnatal collapse (SUPC) is fatal in about half of cases. Epidemiological characteristics of sudden unexpected infant death (SUID) in the first week of life differ from those in the postperinatal age group (7–365 days).

Aim: To describe the characteristics of SUPC resulting in neonatal death.

Methods: We analyzed the Centers for Disease Control and Prevention Birth Cohort Linked Birth/Infant Death Data Set (2003–2013: 41,125,233 births and 37,624 SUIDs). SUPC was defined as infants born ≥ 35 weeks gestational age, with a 5-minute Apgar score of ≥ 7 , who died suddenly and unexpectedly in the first week of life.

Results: Of the 37,624 deaths categorized as SUID during the study period, 616 met the SUPC criteria (1.5/100,000 live births). Eleven percent occurred on the first day of life and nearly three quarters occurred during postnatal days 3–6. SUPC deaths differed statistically from SUID deaths occurring 7–364 days of age, in particular for sex, marital status, and live birth order.

Implications: These data support the need for adequate nurse staffing during the immediate recovery period and for the entire postpartum stay as well as nurse rounding for new mothers in the hospital setting.

Key words: Early neonatal death; Nurse staffing; Sudden unexpected infant death; Sudden unexpected postnatal collapse.

SUDDEN UNEXPECTED POSTNATAL COLLAPSE RESULTING IN NEWBORN DEATH IN THE UNITED STATES

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The sudden collapse of an apparently healthy newborn, or sudden unexpected postnatal collapse (SUPC), is a rare but serious event, fatal in about half of cases and associated with disability in the majority of survivors (Andres et al., 2011; Poets et al., 2011). It has been recommended that SUPC is restricted to any term, or near term, infant who is well at birth, deemed well enough to have routine postnatal care, and collapses unexpectedly, that is, discovered in a state of cardiorespiratory extremis such that resuscitation with intermittent positive pressure ventilation is required, collapses within the first 7 days of life, and either dies, goes on to require intensive care, or develops an encephalopathy (Feldman-Winter et al., 2016; Nassi et al., 2013).

Unfortunately, it has been difficult to study the true extent of SUPC due to a lack of strict definition of inclusion criteria and what entails a “collapse.” Studies vary extensively in inclusion criteria including postnatal age (spanning ≤ 2 hours to ≤ 7 days), gestational age (≥ 35 to ≥ 38 weeks), Apgar score, and severity of collapse. Many studies have indicated that published SUPC estimates are lower than actual collapses that occur in the hospital and only reflect the most severe events (Poets et al., 2011). Thus, it is not surprising that estimates of incidence rates vary quite widely across the literature, from 2.6 to 133 per 100,000 live births (Herlenius & Kuhn, 2013). See box for abbreviations used.

Sudden unexpected infant death (SUID) is a term that encompasses three causes of death categories in infants under 1 year of age as coded in the *International Classification of Diseases, 10th Revision*



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time frame that defines SUEND. The prevalence of SUEND determined in this study was consistent with previous studies that estimate a little over 3% of SUID cases occurred during the first week (Weber et al., 2009).

SUPC deaths represent a subset of the total SUEND cases across the United States. The question arose: if the analysis was restricted to only include infants that are born ≥ 35 weeks gestation with a ≥ 7 Apgar score, would we observe the same distinction between deaths that occur in the first week (SUPC) and postperinatal SUID cases? In this study we used the same computational approaches as the Lavista Ferres et al. (2020) study to determine prevalence and characteristics of SUPC and compare SUPC deaths to postperinatal SUID deaths with the same inclusion criteria.

Methods

We analyzed the Centers for Disease Control and Prevention Birth Cohort Linked Birth/Infant Death Data Set (2003–2013). A death was categorized as SUID if the infant was assigned as one of three cause of death codes defined in the ICD-10: sudden infant death syndrome

(ICD-10): sudden infant death syndrome (R95), deaths from other ill-defined or unknown causes (R99), and accidental suffocation and strangulation in bed (W75). We have recently reported that SUID cases occurring during the first week of life (days 0–6), termed sudden unexpected early neonatal death (SUEND), were a statistically distinct entity from postperinatal SUID (days 7–364; Lavista Ferres et al., 2020) with differing risk factors including maternal smoking during pregnancy, live birth order, marital status, mother's age, and birthweight. Our study provided not only an objective and unbiased argument for categorizing these early neonatal deaths as a separate death category (i.e., SUEND), but also allowed us to statistically determine the

(SIDS; R95), deaths from other ill-defined or unknown causes (R99), or accidental suffocation and strangulation in bed (W75). We defined SUPC as infants born ≥ 35 weeks' gestational age, with a 5-minute Apgar score of ≥ 7 , who died of SUID in the first week of life (< 7 days) (WellChild, 2011). Note that this is a subset of all SUPC cases because we are not including those that collapse and survive (which has been estimated as 50% of cases).

Statistical Analysis

We used the same statistical methodology as our related, SUEND publication. For more detailed methods, please refer to Lavista Ferres et al. (2020). In brief, we first used

a logistic regression model to understand if there is a significant difference between the children who died in the first week from SUPC versus those who died between the first week and the first year of life that followed the same criteria (gestation ≥ 35 weeks, Apgar score ≥ 7). For this, we used the covariates that are known to vary between SIDS/SUID and control populations: ICD-10, place of birth, maternal smoking, mother's education, mother's race, mother's marital status, father's race, sex of infant, live-birth order, prenatal care visits, birth weight, birth method, and gestation (Kinney & Thach, 2009). To measure the difference between the SUPC cases for each age of death subset versus deaths that occur after the first week with the same inclusion criteria, the area under the receiver operating characteristic curve (AUC) for each model was used. The AUC quantifies the overall ability of the model to discriminate between two populations. To measure the significance level of the AUC, a permutation test was computed.

A second set of logistic regression models were then used to compare adjusted odds ratios of SUPC deaths versus those who died between 7 and 364 days. For both logistic regressions, we use a control group using non-SUID live births who survived to the first year with the same definition criteria (gestation ≥ 35 weeks, Apgar score

≥ 7 ; $N = 35,403,668$). For both models, we use the same set of covariates: maternal smoking, mother's education, mother's race, mother's marital status, father's race, sex of infant, live-birth order, prenatal care visits, birth weight, birth method, and gestation using the same SUPC criteria defined above.

Results

There were 41,125,233 births and 37,624 deaths that were categorized as SUID. Of the total 1,260 SUEND cases in our study, 616 (49%) met the SUPC inclusion criteria (rate = 1.5/100,000 live births). A STROBE flow diagram outlines the selection process for each population that was analyzed (Figure 1).

Figure 2 shows the number of SUPC deaths by day of life. Sixty nine (11%) of the infants died from SUPC during the first day of life. Nearly three quarters (72%) of the SUPC deaths in this study occurred during postnatal days 3–6. The exact time at which the infant originally collapsed is unknown in this data set. One could hypothesize that deaths may have been significantly delayed by cardiorespiratory support; however, in this data set, only 17 (3%) of the 616 infants that died of SUPC were admitted to the neonatal intensive care unit (NICU).

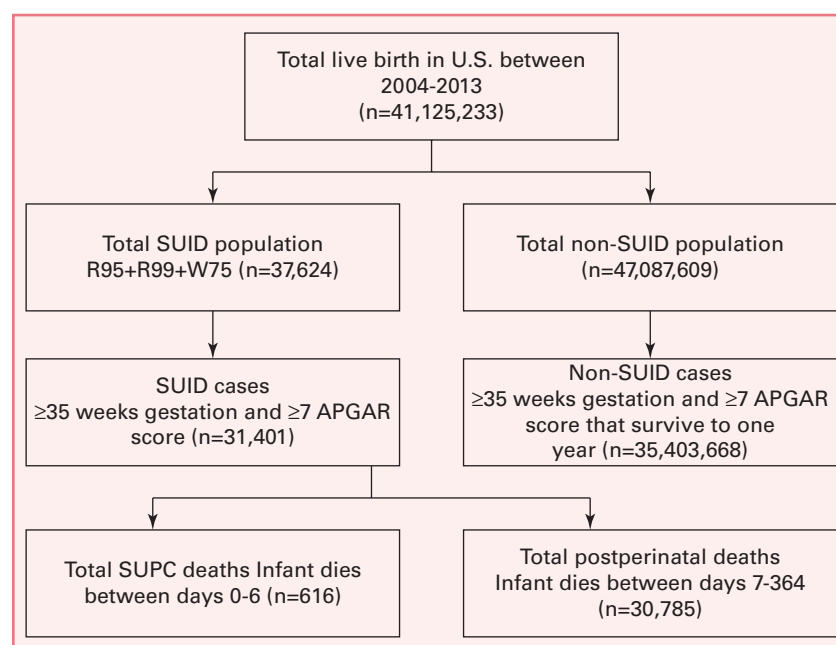
We were unable to directly determine the percentage of deaths that occurred in a hospital setting. However, we attempted to extrapolate the percentage of deaths based on the observation that in the United States, during the time frame included in the data set, the mother and newborn typically stay in the hospital for the first 48 hours of postnatal life after a vaginal birth and 96 hours after birth by cesarean. Thus, combining SUPC cases that occurred during days 0–1 after a vaginal birth (or when birth method is unknown or not-stated) and those that occur during days 0–3 for a cesarean birth resulted in 22% (136) of SUPC deaths that most likely occurred in the hospital setting. This is a conservative number given that this does not include a percentage of cases in which birth method is recorded as unknown or not-stated, but were actually births by cesarean that passed away on day 2 or 3. In addition, if the baby collapses within the standard hospital stay window, but does not pass away until after the normal discharge day, this death would not be captured in our estimate.

To further analyze SUPC, we built a logistic regression computational model. We found that even though day of death was not input into the model, it was able to distinguish between deaths that occur in the first week of life

Abbreviations

aOR, adjusted odds ratio	SIDS, sudden infant death syndrome
AUC, area under the curve	SUEND, sudden unexpected early neonatal death
CI, confidence interval	SUID, sudden unexpected infant death
ICD-10, <i>International Classification of Diseases, 10th Revision</i>	SUPC, sudden unexpected postnatal collapse
NICU, neonatal intensive care unit	

FIGURE 1. STROBE FLOW DIAGRAM OUTLINING THE SAMPLE SELECTION PROCESS



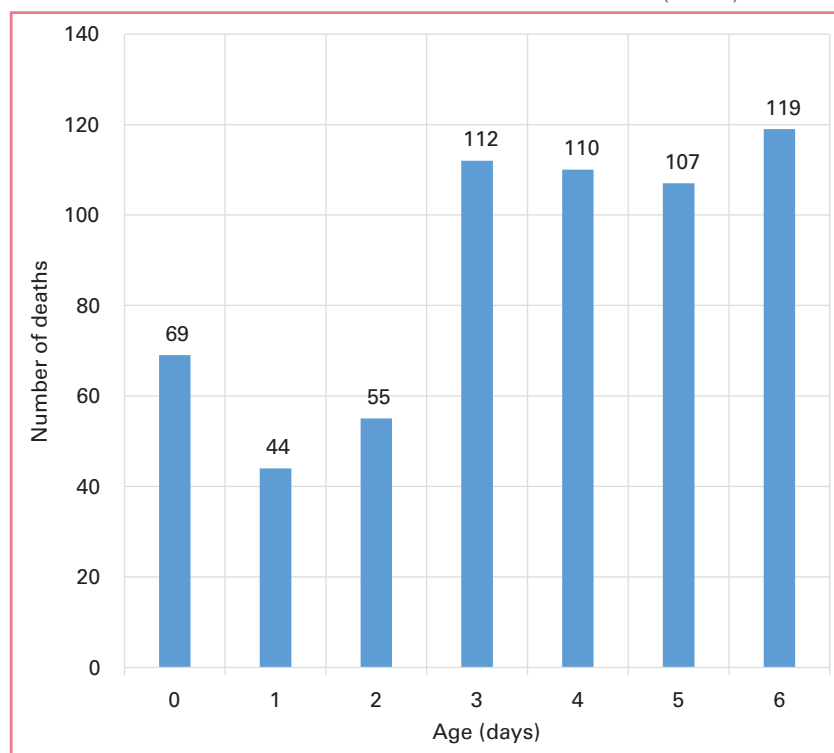
($N = 616$) versus those that occur between postperinatal days 7–364 ($N = 30,785$) with an AUC of 66% (both groups: gestation ≥ 35 weeks, Apgar score ≥ 7). The two groups significantly differed in three variables: sex, marital status, and live birth order (Table 1). Marital status is not a risk factor for SUPC death; however, being unmarried is a risk for deaths after the first week (aOR: 1.49, CI: 1.43–1.55). The second and higher live birth order for SUPC cases in the first week exhibited a lower risk of death compared with the first live birth (aOR: 0.77, CI: 0.61–0.98). The opposite was true for later deaths wherein progressively increasing live birth order increased the risk of death (aOR: 1.97, CI: 1.89–2.05). There does not seem to be a sex bias for SUPC deaths (51% are males; similar ratio to all live births in the United States over the same time period); however, male sex is a risk factor in the postperinatal period.

Given known dangers of the first day of life (Oza et al., 2014) one could hypothesize that results of the model are heavily impacted by deaths that occur in the first 24 hours (day 0) and deaths that occur in the NICU. To address this, we re-ran the model after removing the 69 deaths that occurred on day 0 and the 17 NICU cases and found that the AUC of the model remained unchanged at 66%.

Clinical Nursing Implications

Reported incidence rate of SUPC includes instances of collapse that do not result in death (sometimes referred to as

FIGURE 2. DISTRIBUTION OF SUPC DEATHS BY AGE (DAYS)



apparent life-threatening events [ALTE]) or, more recently, brief resolved unexplained events (Tieder et al., 2016). Variation in severity of the collapse probably accounts for the widely varying reported rates of SUPC. Restricting our cases to infants that die avoids this problem. We found that SUPC resulting in death occurred at a rate of 1.5/100,000 live births. Given that SUPC is reportedly fatal in approximately 50% of cases, our estimated total SUPC incident rate would be about 3/100,000 live births.

TABLE 1. COMPARING RISK OF VARIOUS FACTORS THAT REACHED STATISTICAL SIGNIFICANCE BETWEEN SUPC (0–6 DAYS) AND POSTPERINATAL (7–364 DAYS) SUID POPULATIONS

	Controls <i>n</i> = 35, 403,668	SUPC, 0–6 d <i>n</i> = 616				SUID, 7–364 d <i>n</i> = 30,785			
	%	%	aOR	CI	<i>P</i>	%	aOR	CI	<i>P</i>
Sex									
Male	51.0%	50.3%	Reference	—	—	58.3%	Reference	—	—
Female	49.0%	49.8%	0.93	0.77–1.13	0.48	41.7%	0.72	0.68–0.74	<0.001
Live birth order									
First live birth	39.9%	42.3%	Reference	—	—	28.6%	Reference	—	—
Second live birth	32.0%	24.0%	0.77	0.61–0.98	0.037	32.3%	1.97	1.89–2.05	<0.001
Marital status									
Not Married	39.0%	54.5%	1.15	0.92–1.43	0.22	66.1%	1.49	1.43–1.55	<0.001
Married	61.1%	45.5%	Reference	—	—	33.9%	Reference	—	—

aOR: adjusted for smoking, mother's education, mother's race, mother's marital status, father's race, sex of infant, live birth order, prenatal care visits, birth weight, birth method, and gestation

This estimate is on the lower end of published estimates even though we include SUPC deaths across the entire first week of life.

Only 11% of deaths from SUPC occurred during the first day of life, and nearly three quarters (72%) occurred during postnatal days 3–6. This contrasts with the study by Herlenius and Kuhn (2013) that reported that half of SUPC cases occur after the first 24 hours. Thus, it is important to consider SUPC not only for the first 24 hours. Here we provide a statistically based argument that the definition of SUPC should include cases that occur in the first 7 days of life.

A major strength of this study is the large sample size. We used advanced statistical methods to analyze every death in the United States over an 11-year period that met the definition of a SUPC death (with over 38 million controls), compared with most studies that have a much more limited population size and geographical distribution.

We have previously shown that SUEND should be considered as a discrete entity from postperinatal SUID (Lavista Ferres et al., 2020). Collectively, these data suggest our original conclusions hold true even if the data are restricted to babies that are born apparently healthy (i.e., gestation ≥ 35 weeks, Apgar ≥ 7). Specifically, infants

that die suddenly and unexpectedly in the first week are a statistically different entity than infants that pass away between 7 and 364 days.

Benefits of breastfeeding are well established (American Academy of Pediatrics [AAP], 2012). AAP recommends an infant be exclusively breast fed for the first 6 months of life (AAP, 2012). AAP also recommends supine sleeping position as the safest sleep position to prevent SUID and that infants sleep in their parents' room on a separate surface, ideally for the entire first year, but at least for the first 6 months. This should begin in the hospital after birth. To improve breastfeeding rates, the Joint Commission recommends skin-to-skin contact immediately following birth and rooming-in to help mothers recognize early feeding cues (Joint Commission, 2018).

Published risk factors for SUPC include the first 2 hours of life, prone position of infant, skin-to-skin care, unsupervised breastfeeding during the first 2 hours of life, maternal fatigue, primiparous mothers, and maternal distractions including use of a smartphone (Becher et al., 2012; Dageville et al., 2008; Pejovic & Herlenius, 2013; Poets et al., 2011). A limitation of this study is that these risk factors could not be examined as they were not routinely collected. An abundance of research supports

TABLE 2.

Guidelines and Standards from Professional Organizations on Maternal–Newborn Safety during Postpartum Hospitalization
Immediate Recovery Period
During the immediate postpartum recovery period there should be 1 nurse for the mother and 1 nurse for the baby. When condition of mother and baby are determined to be stable and the critical elements are met, 1 nurse can care for both the mother and the baby. Critical elements for the mother's care and baby's care are detailed in the AWHONN nurse staffing guidelines (2010). The ratio of 1 nurse to 1 woman and her baby (after the critical elements are met) during immediate postpartum recovery should continue for at least 2 hours, or longer if complications are encountered. The nurse should have no other patient assignments (AAP & ACOG, 2017; AWHONN, 2010).
During the first 2 hours after birth, all newborns in skin-to-skin contact and breastfeeding should be continuously monitored by qualified professional personnel including nurses, midwives, nurse practitioners, physicians, and/or lactation consultants (AAP, [Feldman-Winter et al.] 2016; AWHONN, 2020).
Important aspects of safe newborn positioning during skin-to-skin include the ability to visualize baby's face; the baby's head in a "sniffing" position, turned to the side, with a straight neck to ensure an open airway; the baby's shoulders and chest facing mother with blankets covering the back; and flexed legs (AAP [Feldman-Winter et al.], 2016; AWHONN, 2020).
Mother–Baby Couplet Care
The nurse-to-patient ratio for normal healthy mother–baby couplets should be no more than 1 to 3 (AAP & ACOG, 2017; AWHONN, 2010).
During postpartum hospitalization, regular monitoring (including every 30 minutes for high-risk mothers and babies) of mother–baby couplets is recommended (AAP [Feldman-Winter et al.], 2016).
Hourly rounding on mother–baby couplets is recommended so mothers or other caregivers noted to be drowsy can be assisted to place the baby in a bassinet (Joint Commission, 2018).
Healthy newborns with risk factors for sudden unexpected postnatal collapse (SUPC) should be frequently assessed during all skin-to-skin contact and breastfeeding sessions (AWHONN, 2020).
Parents should be cautioned against falling asleep with their newborn in the bed or co-sleeping with their newborn (AAP [Feldman-Winter et al.], 2016; AWHONN, 2020; Joint Commission, 2018).
Caregivers should be taught safe positioning of the newborn as detailed per AAP (Feldman-Winter et al., 2016) to ensure airway protection (AWHONN, 2020).

Note. Adapted from AAP (Feldman-Winter et al., 2016), AAP & ACOG (2017), AWHONN (2010), AWHONN (2020), and Joint Commission (2018)

CLINICAL IMPLICATIONS

- The sudden collapse of an apparently healthy newborn, or sudden unexpected postnatal collapse (SUPC), is fatal in about half of reported cases and nonfatal cases often lead to long-term neurological sequelae.
- Knowledge of SUPC by maternity nurses has been shown to be poor. Even though cases of SUPC resulting in death are rare (1.5/100,000 live births in this study), it is important for maternity nurses, lactation consultants, midwives, and physicians to be aware of the factors associated with SUPC to mitigate any risk of collapse (i.e., the first 2 hours of life, prone position of the infant, skin-to-skin care, unsupervised breastfeeding during the first 2 hours of life, maternal fatigue, primiparous mothers, and maternal distractions such as use of a smartphone).
- There are a multitude of benefits to skin-to-skin care and breastfeeding. As they are SUPC risk factors, however, a nurse should continuously monitor mother and baby at minimum during the first 2 hours of the newborn's life.
- Safe newborn positioning during skin-to-skin includes the ability to visualize baby's face; the baby's head in a "sniffing" position, turned to the side, with a straight neck to ensure an open airway; the baby's shoulders and chest facing mother with blankets covering the back; and flexed legs.
- Based on the average length of postpartum hospital stay, we estimate that only a quarter of fatal SUPC cases occur in the hospital, so it is imperative that parents are educated about the risks of SUPC and SUID before being discharged. Specifically, parents should be counseled to always: place their baby supine to sleep, ensure baby is returned to their own separate space if taken into the parental bed for breastfeeding, avoid falling asleep with baby on the parent, be constantly aware of baby's position when using a smartphone or otherwise distracted, and, if possible, accept extra help from friends and family to mitigate fatigue.
- Overall, these data support the need for adequate nurse staffing not only during the immediate recovery period, but all of the postpartum stay and for nurse rounding for new mothers in the hospital setting.

the benefits of skin-to-skin care (Hubbard & Gattman, 2017; Moore et al., 2016) and breastfeeding (Gertosio et al., 2016) and parents should be encouraged to engage in these activities. However, the fact that they are risk factors for SUPC underscores the necessity for continuous supervision by a nurse with mother and baby during at least the first 2 hours of the newborn's life.

Knowledge of SUPC by maternity nurses has been shown to be poor (Addison & Ludington-Hoe, 2020). Although SUPC is rare, it is important for midwives and maternity nurses to be aware of the factors associated with SUPC, so they can mitigate the risk (Association of Women's Health, Obstetric and Neonatal Nurses [AWHONN], 2020). Educating parents about these factors may reduce the risk of

SUID during the first year of life. Specifically, parents should be counseled to: always place their baby supine to sleep, ensure baby is returned to their own separate space if taken into the parental bed for breastfeeding, avoid falling asleep with baby on the parent, be constantly aware of baby's position when using a smartphone, and, if possible, accept extra help from friends and family to mitigate fatigue.

Based on the average length of postpartum hospital stay, at least about a quarter of the SUPC cases are occurring in the hospital setting, and we suspect that the actual figure is significantly higher. These data support the need for adequate nurse staffing not only during the immediate recovery period, but for the entire postpartum stay and for nurse rounding for new mothers and babies in the hospital setting (AAP & American College of Obstetricians and Gynecologists [ACOG], 2017; AWHONN, 2010; Feldman-Winter et al., 2016; Joint Commission, 2018). Table 2 provides a summary of guidelines and standards from professional organizations for maternal-newborn safety during the postpartum hospitalization. ✚

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