A LITERATURE REVIEW OF THE PHYSIOLOGICAL EFFECTS OF EARLY POSTPARTUM SKIN-TO-SKIN CONTACT AND THE RISK OF SUDDEN UNEXPECTED POSTNATAL COLLAPSE FOR HEALTHY, TERM NEONATES

by

Shan Robertson

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Approved by: ______________________________
Catherine Sullivan, MPH, RD, IBCLC Advisor

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Kori Flower, MD, MS, MPH Reader

Abstract

Early postpartum skin to skin contact (SSC) is a resurging practice that has been proposed to facilitate breastfeeding, induce analgesia, and improve thermoregulation in healthy infants. However, the increase in SSC practices in developed countries has coincided with an increase in published case reports of sudden unexpected postnatal collapse (SUPC), and this places into question the safety of the practice for many parents, nurses, physicians, and hospitals. The objective of this literature review is to examine studies published between 2006-2016 on the physiological effects of SSC for healthy, term neonates as well as the epidemiology, risk factors, and pathophysiology of SUPC. Additionally, it will discuss literature-based prevention measures for SUPC to increase the safety of SSC without losing potential benefits.

Table of contents

Introduction

Early postpartum skin-to-skin contact (SSC) between a mother and newborn is a historical practice during which babies are held naked on their mother's bare chest at birth, a practice beneficial for the baby's temperature regulation, initiation of innate breastfeeding behaviors, and thus neonatal survival (1). Various benefits have been ascribed to SSC, including improved initiation and increased duration of breastfeeding, neonatal thermoregulation, and neonatal analgesia during painful procedures (1). However, the increase in SSC worldwide and especially in developed nations has been associated with an increase in published case reports of sudden unexpected postnatal collapse (SUPC) in newborns (2), many of whom were undergoing SSC at the time of collapse (3), and this places into question the safety of the practice for many parents, nurses, physicians, and hospitals.

This thesis aims to review the primary research literature published worldwide within the last decade (2006-2016) pertaining to the major physiological effects of SSC in healthy, term newborns, including effects on breastfeeding initiation and duration, neonatal pain relief, and neonatal temperature regulation, to determine if there have been changes to the body of evidence surrounding this practice and to propose future studies that would refine our understanding of SSC for healthy infants. Additionally, it will review the literature on SUPC, including epidemiology, pathophysiology, risk factors, and sequelae, as well as discuss recent literature-based prevention recommendations and provide suggestions for future steps in the research and prevention of this rare but catastrophic event that can precipitate neonatal death.

Background

Skin-to-skin contact is defined by the American Academy of Pediatrics (AAP) as "the practice of placing infants in direct contact with their mothers or other caregivers with the ventral skin of the infant facing and touching the ventral skin of the mother/caregiver (chest-to-chest)" (4). The infant is naked or dressed only in a diaper to maximize direct skin contact, and the dyad is covered with blankets to maintain temperature leaving only the infant's head uncovered. The World Health Organization (WHO) recommends that all healthy babies, regardless of the mode of delivery or intended feeding method, initiate SSC with their mothers immediately after birth if the mother is stable, awake, and alert, and that SSC continue for at least 1 hour after birth and beyond throughout infancy as desired and appropriate for both mother and infant (5).

However, despite these recommendations, mother-infant separation is common in modern labor and delivery and postpartum units, especially those of developed nations. Healthy term infants are routinely taken to the warmer or nursery immediately after birth for APGAR scoring and assessment, maternal rest, bathing, weighing, vaccines, vitamin K administration, hearing screens, and other common neonatal procedures. Additionally, babies are often dressed and/or swaddled before being returned to their mothers. Many studies have been conducted on the physiological effects of SSC in healthy term infants, but most studies in the past were conducted in developing countries where SSC has always been and continues to be the standard of care, while case reports of SUPC are published mostly out of developed nations where SSC is a resurging practice. This review will incorporate studies in both developed and developing nations to ascertain whether evidence continues to support immediate SSC for full-term healthy newborns and to identify gaps in the existing evidence base on the effect and safety of SSC.

Definition of SUPC

The definition of SUPC varies depending on author and population, but one commonly-cited definition is that of the British Association of Perinatal Medicine, which is any infant >35 weeks gestation who meets the following criteria (4):

1. 5-minute APGAR≥7 and deemed healthy enough for routine care
2. Experiences cardiorespiratory collapse within the first 7 days of life requiring at least positive-pressure ventilation
3. Either dies, requires intensive care, or develops encephalopathy
4. Other causes of collapse, such as sepsis, cardiac disease, metabolic disease, etc., are excluded

The authors of the articles incorporated into the SUPC portion of this review utilize different definitions with varying gestational ages at delivery, hours of life, amount of resuscitation required, and whether a plausible cause of death was found, and therefore comparison between them may not provide an accurate picture as to the incidence of SUPC. In particular, two of the articles defined SUPC as collapse specifically while the infant is in SSC, which would provide a highly skewed representation of the risk of SUPC that is associated with SSC. Definitions of SUPC for articles in that section of this review are provided in Appendix A.

Problem statement and relevance to MCH

SSC is a low-cost intervention feasible in both developed and developing nations that has been hypothesized to impact both the short- and long-term health of both mothers and babies through bonding, improved neonatal homeostasis, and improved breastfeeding initiation and duration (1). Although there is a significant body of literature published on the physiological effects and benefits of kangaroo care for preterm, low birthweight, and NICU infants, SSC for healthy infants has not been as extensively studied.

Additionally, the concern for SUPC often dominates the conversation surrounding SSC for healthy, term infants, since unnoticed SUPC is rare in NICU infants due to extensive continuous cardiorespiratory monitoring. Although the concern for SUPC is warranted due to its potentially catastrophic consequences, many providers and hospitals deny mothers and babies the opportunity for SSC care due to these concerns.

Search strategy

For this review, I conducted a search on PubMed in September 2016 using the search term ("Infant, Newborn"[Mesh] OR newborn[tw] OR newborns[tw] OR neonate[tw] OR neonates[tw]) AND ("skin to skin"[tw] OR kangaroo[tw]) AND (term[tw] OR normal[tw] OR healthy[tw]). Inclusion criteria were articles published between January 2006-September 2016 in English, relevant to the topics of neonatal physiological effects of immediate postpartum SSC and SUPC, and pertaining specifically to healthy, term, normal birthweight neonates.

For the physiological effects of SSC analysis, only observational and randomized studies with intervention and control groups specifically studying the effect of early postpartum SSC in healthy term neonates were included. Literature reviews were excluded to facilitate original interpretation of primary research. For SUPC, all published case reports and prospective and retrospective studies found through the search criteria were incorporated. After abstract and full text review, a total of 24 articles (16 for effects, 8 for SUPC) met all the search criteria and comprised this review. See Appendix B for the flowchart of this search.

Critical review

Physiological effects

Included studies

Sixteen articles were selected for the physiological effects section of this review. Fourteen were randomized controlled trials and two were prospective cohort studies. Five papers studied the effect of SSC on breastfeeding, eight studied the effect on neonatal pain response, three studied the effect on thermoregulation, and three studied other effects such as bonding, crying in the absence of painful stimulus, and newborn weight loss. (Two papers studied multiple factors so these numbers do not add up to 14.) Studies were conducted in both developed and developing nations, with four studies in Iran, three in the USA, two in India, and one each in Brazil, Japan, Russia, South Korea, Spain, Sweden, and Turkey. All papers included only healthy infants born between 37-42 weeks gestation, born via vaginal delivery or planned cesarean section under spinal anesthesia to mothers without pregnancy complications, with an APGAR of at least 7 at 5 minutes. Please see Appendix C for an informational chart of all the articles used in this part of the review.

Breastfeeding

SSC is hypothesized to be beneficial for the initiation and duration of breastfeeding through stimulation of maternal lactation hormones such as prolactin and oxytocin as well as activation of the newborn's natural breastfeeding reflexes (1). Of the five studies on SSC and breastfeeding, four used the Infant Breastfeeding Assessment Tool (IBFAT), a validated tool that scores the successfulness of a single breastfeeding session based on readiness, rooting, latching, and sucking, to assess a breastfeeding session during the hospital stay after delivery and compared scores between infants who received SSC vs "conventional care," which was defined differently in each study. (IBFAT criteria can be found in Appendix D.) Additionally, four studies followed up with mothers immediately before discharge and/or outpatient to assess breastfeeding exclusivity at set timepoints.

Beiranvand compared infants born in Iran who were randomized to be placed in SSC with their mothers for one hour after planned cesarean delivery when their mothers were in recovery (n=46) with similar infants dressed and placed in a cot (n=46) (6). This study found that more than twice the percentage of infants in SSC showed readiness to breastfeed in the 1st hour (52.2% vs 25%, p=0.021), and that 87% of those in SSC demonstrated "good or moderate" sucking at the 1st breastfeeding attempt vs 63.7% of those in routine care (6). However, this study did not find a statistically significant difference in latching and rooting (6). This study did not follow up with the mothers to assess exclusivity after discharge.

In a U.S. hospital, Moore randomized 20 infants to be either placed in SSC for the 1st 2 hours (n=10) or to be swaddled in blankets and held by their mothers (n=10) after spontaneous vaginal delivery (7). Researchers found that, while SSC dyads had higher mean IBFAT score during the 1st breastfeeding (8.7 vs 6.3, p=0.02) and achieved effective breastfeeding sooner (935 min/15 hours vs 1737 min/19 hours after birth, p=0.04), there was no significant difference in the number of breastfeeding problems reported or in breastfeeding exclusivity at 1 month (7). Notably, because the study was designed to assess infant suckling ability, babies that had feeds of bottled breastmilk were counted as not exclusively breastfeeding. Because this study only included 20 dyads, it was not powered to show a small difference between groups in breastfeeding exclusivity. Also, mothers who consented to participate were overwhelmingly motivated to breastfeed, white, college-educated, and married, and it's unclear as to whether these results would apply to a more diverse study group.

Srivastava and Thukral both conducted RCTs in India that randomized newborns to either be placed in SSC immediately after spontaneous vaginal delivery for at least 2 hours (n=122 for Srivastava, n=20 for Thukral) or clothed, wrapped in a blanket, and placed next to mom (n=188 for Srivastava, n=21 for Thukral) (8,9). Srivastava found that a breastfeeding session scored via IBFAT within the 1st 24 hours demonstrated higher mean scores in SSC infants (9.55 vs 6.77, p<0.0001) (8). However, the smaller study by Thukral found no significant difference in median IBFAT scores between groups at 36-48 hours (9), although it was not powered to show such a small difference given the sample sizes. However, both studies found higher exclusive breastfeeding rates at 6 weeks for infants in the SSC group (Srivastava: 85.2% vs 63.6%, p<0.0001; Thukral: 90% vs 28.6%, 95% CI for risk ratio 1.6-6.3). Thukral's protocol mandated that none of the infants were to receive SSC at any other point during the hospital stay, including during the scored breastfeeding session, whereas this provision was not present for Srivastava's study. Also, Thukral's study obtained the IBFAT score between 36-48 hours, as opposed to the <24 hours IBFAT scores obtained by other studies.

Similar to the Indian studies and in contrast with the USA study, Suzuki found in a prospective cohort that primiparous mothers and neonates receiving early SSC starting within 1-5 minutes after birth for at least 60-90 min (n=272) in a Japanese hospital had higher rates of exclusive breastfeeding at 1 month than those not receiving early SSC (n=131) (59.6% vs 45.8%, p=0.009) (10). There were no significant differences between groups in maternal age, gestational age at delivery, operative vaginal delivery rate, birth weight, 1 minute APGAR, maternal blood loss postpartum hemorrhage rates, and incidences of severe perineal lacerations. The authors did not explain the care that was provided to those infants not receiving early SSC, and mothers decided whether they would have early SSC with her infants. Therefore, it's possible that mothers that were strongly motivated to breastfeed were more likely to elect for early SSC.

One major limitation present in all studies reporting an IBFAT score except for Thukral's was that, due to the nature of the intervention, the investigators scoring the IBFAT could not be blinded as to SSC vs control status, which may have influenced their assigned IBFAT score. Thukral obtained an IBFAT score after early SSC had terminated and thus could blind evaluators to group assignment, and researchers in that study found no difference in IBFAT score. This could be either be due to the benefits of early SSC on IBFAT score leveling out over time, the benefit being strongest when breastfeeding was attempted in SSC, or the lack of power of the study to reveal a small difference.

Overall, three of the four studies that measured IBFAT scores found that SSC infants had higher scores than control infants within the 1st 24 hours, However, one study obtained a score between 36-48 hours in infants that had undergone SSC after delivery but were not in SSC at the time of the scored breastfeeding session and did not find a significant difference in score. Also, three of the four studies that measured breastfeeding exclusivity after discharge found higher rates of exclusive breastfeeding for infants that had been randomized to SSC, with the study conducted in the USA being the exception.

Neonatal pain relief

It is postulated that SSC may induce the release of opioids or neuropeptides in the infant that provide analgesia during a painful stimulus (11). Studies have shown that unalleviated pain early in life can result in negative long-term effects, including decreased pain tolerance and emotional and behavioral issues (12,13). Because many providers are hesitant to provide pharmacological pain relief to newborns for brief procedures due to the risk of adverse medication effects, nonpharmacological methods for immediate pain reduction are valuable in this population.

Eight of the articles in this review studied the effect of SSC on neonatal response to a painful procedure, either intramuscular injection of Vitamin K or a vaccine or heel lance for newborn metabolic screening. SSC time prior to stimulus varied from 2-30 minutes, and the neonate’s age at which the stimulus was administered ranged from 2-72 hours after birth. Control groups varied, from being placed supine in a bassinet in the nursery to being clothed/wrapped in a blanket and placed in a bassinet next to the mother. Assessment of pain was done using measures such as recorded crying time, heart rate, oxygen saturation, or validated scoring tools such as the Neonatal Facial Coding System (NFCS), Neonatal Infant Pain Scale (NIPS), Premature Infant Pain Profile (PIPP), Anderson Behavioral State Scale (ABSS) or a combination of the above. (Criteria for each of the tools can be found in Appendix E.) Four of the studies had an additional group or groups combining SSC with another pain-relieving intervention, either oral sweetener or breastfeeding, and in addition studied the effect of the combined intervention as compared to SSC alone on pain expression.

Kashaninia, Saeidi, and Kostandy all conducted RCTs in Iran (Kashaninia and Saeidi) and the USA (Kostandy) directly comparing infants who received SSC starting from 10-30 minutes before either a Vitamin K injection or the Hepatitis B vaccination with infants who were placed supine in the nursery or in a bassinet near their mother before injection. Kashaninia and Saeidi found that a significantly lower percentage of infants in the SSC group were rated as in severe pain (NIPS >4) after the injection as compared to the control group (Kashaninia: 6.6% vs 27.5%, p=0.021; Saeidi: 3% vs 30%, p<0.001) (14,15). Saeidi and Kostandy both found that recorded cry time after injection was decreased in SSC neonates vs control (Saeidi: crying time not specified, p=0.008; Kostandy:15.8s vs 71.8s, p=0.007) (12,14). Kostandy found that SSC neonates spent less time during and after injection in ABSS states 10-12 (fussy and crying) (During: 77% vs 95%, After: 42% vs 12%) (12). Seo conducted a similar prospective cohort study in Korea that found that PIPP scores and heart rate were significantly lower in SSC infants vs control infants at one and two minutes after heel lance, although the control group protocol was not described in the study (16).

Chermont's RCT in Brazil compared 12-72 hours old infants that received both SSC and oral dextrose 2 minutes prior to Hepatitis B vaccination to those who received only one or neither of the interventions and found that SSC alone or dextrose alone did not significantly affect NFCS or NIPS scores at the time of injection, but that both interventions combined did decrease injection pain scores (6.2 for combined intervention vs average 7.2 for other groups). All pain scores were decreased with intervention 2 minutes after injection as compared to control, but the combination of SSC and dextrose was significantly superior to either alone (0.6 for combined vs 1.8 for SSC only, 2.1 for dextrose only, 4.0 for standard care). PIPP scores were lower during SSC regardless of dextrose administration, and isolated dextrose didn't have an impact on PIPP scores (11). In this study, only 2 minutes of SSC prior to injection was necessary to produce a significant pain alleviation response.

Fallah, Marin-Gabriel, and Okan conducted RCTs in Iran, Spain, and Turkey, respectively, comparing the pain response between infants being breastfed either alone or in conjunction with SSC, SSC-only infants, and control infants supine on a surface not in contact with their mother during either BCG vaccination (Fallah) or a heel lance for metabolic screening (Marin-Gabriel and Okan). Fallah found that NIPS scores in breastfeeding infants during, one, and two minutes after vaccination were significantly lower than those in SSC only infants, which were lower than scores in control infants. Crying time followed the same trend (26.61s for breastfeeding infants, 45.12s for SSC only infants, 63.25s for swaddled infants, p=0.0001) (13). It was not specified whether the infant was in SSC during breastfeeding for this study. Marin-Gabriel added a group of infants who received 24% oral sucrose two minutes before heel lance along with SSC during the procedure to the previously mentioned three groups and found that the combined breastfeeding and SSC group had a significantly lower mean NIPS score 10 seconds after heel lance than the other groups (1 for BF+SSC, 2 for sucrose+SSC, 4 each for SSC only and sucrose only, $p<0.01$) (17). Both BF+SSC and sucrose+SSC had significantly lower crying time percentages than the other groups (3% for BF+SSC, 5% for sucrose+SSC, 52% for SSC only, 23% for sucrose only, $p=0.03$) (17) The study was finalized after the midpoint analysis because it was deemed unethical to continue the study given the higher NIPS score for the SSC only and sucrose only groups. Okan found that infants in BF+SSC and SSC only had a significantly smaller rise in heart rate and drop in oxygen saturation at 0, 1, 2, 3, 4, and 5 minutes following the painful stimulus than the infants lying on the table at the time of heel lance, although all values stayed within the normal range for both variables (18). Additionally, infants in the first two groups had a decreased total crying time (48s for BF+SSC, 65s for SSC only, 184 s for lying on table) (18). The difference between BF+SSC and SSC only in crying time was not statistically significant, but crying time in the control group was significantly higher. NFCS scores were obtained for SSC only and control infants (facial actions of breastfeeding infants couldn't be observed on videotape) and were significantly higher after 1 minute following heel lance for control infants.

A major limitation of all these studies was that infants in SSC were compared with infants placed supine on a surface without interaction with their mother, making it unclear whether it is the skin to skin contact or the interaction with the mother that provided comfort and analgesia. None of the studies mentioned whether their newborns received SSC immediately after birth, which may affect their response to SSC later during a painful procedure. Only one study gave a timeframe for the neonatal age at which the painful stimulus was administered, which may influence both pain response and the effect of SSC and other interventions. Additionally, due to the nature of the intervention, investigators scoring infants on pain scale could not be blinded to group status, although researchers analyzing crying time, which was audiotaped, and objective measures such as heart rate and oxygen saturation were blinded to group status.

Despite these limitations, all eight studies reviewed reached the same conclusion- that infants in SSC during the stimulus expressed less pain than controls and recovered faster physiologically. Additionally, the three studies looking at combination with breastfeeding and/or oral dextrose/sucrose found that the combination was more efficacious that either intervention alone.

Thermoregulation

Oxytocin, which is released in the mother's body during SSC, is theorized to increase the temperature of the mother's breasts to help keep the SSC infant warm (6). Additionally, the body temperature of the mother can also transfer directly to an infant in SSC. Three studies compared the effect of SSC vs conventional care on newborn body temperature. Beiranvand found that both infants in SSC and infants dressed and placed in a cot in the recovery room after cesarean delivery remained euthermic and had no significant differences in means or standard deviations of temperatures as measured by an infrared forehead thermometer before, during, or after the intervention (6). Srivastava found that, after vaginal delivery, all infants randomized to SSC were euthermic, whereas

7.9% of those clothed, wrapped, and placed next to their mother were found to be in cold stress at 2 hours of life (8).

A study at a U.S. hospital intended to compare SSC vs radiant rewarming after the 1st bath at 4-12 hours after delivery found that, of 96 infants in SSC, 91 were successfully rewarmed (axillary temperature was at least 36.4 degrees Celsius at 30 minutes after initiation of SSC or radiant rewarming), and the remaining five that required rescue rewarming under the radiant warmer were found to have either inadequate skin to skin contact or inadequate coverage with blanket (19). While this study was originally intended as a pragmatic trial to compare SSC vs radiant rewarming, 96 of the first 100 mothers enrolled chose SSC, and thus the study was terminated early and redirected to assess safety and effectiveness of SSC for rewarming (19).

In summary, all studies reviewed found that properly-conducted SSC was equivalent to or superior to conventional care for neonatal thermoregulation. Additionally, in the US study, SSC was overwhelmingly chosen by mothers over radiant rewarming when they were provided with these options. However, the amount of evidence pertaining to this effect is sparse compared to the other effects reviewed here. More research is needed to evaluate SSC vs radiant rewarming at birth, as none of the randomized controlled trials reviewed here specifically compared these two groups.

Other purported effects

There have been other effects attributed to SSC, including improved mother-baby bonding, decreased crying in the absence of painful stimulus, and decreased newborn weight loss. These effects are discussed in three of the studies included in this review.

Bystrova conducted a study in Russia randomizing dyads to 4 different groups: 1) infant in SSC starting after the 1^{st} 25 min after birth + rooming in postpartum, 2) infant dressed and placed in mother's arms after birth + rooming in postpartum, 3) infant in nursery both immediately after birth and postpartum, and 4) infant in nursery after birth + rooming in postpartum (20). Mother-infant interactions were videotaped 1 year later and assessed using the Parent-Child Early Relational Assessment (PCERA) by researchers blinded to group affiliation. It was found that mothers in group 2 were more sensitive and consistent towards their babies than mothers in group 4 (p=0.031), indicating that immediate postpartum separation had a negative effect on bonding that was not overcome by later rooming-in. Infants in group 1 were less dysregulated and irritable compared to infants in groups 3 and 4 (p=0.011 and 0.026, respectively), demonstrating a positive effect of SSC on infant regulation (20).

Erlandsson studied the effect of SSC with the father after planned cesarean delivery on infant crying time by randomizing infants to SSC with father (n=15) vs conventional care in a cot (n=14) during the 1^{st} 2 hours after birth. Mean crying time was decreased in SSC infants (13.4 s vs 33.4 s per 5-minute period, P<0.0001), and crying decreased within 15 minutes of starting SSC with the father (21). This article was notable for being the only one to study SSC with a caregiver other than the mother.

Srivastava studied, among other effects, the impact of immediate SSC on neonatal weight loss and found that infants that had been randomized to SSC had less weight loss at discharge and 4-5 days after birth as compared to those clothed, wrapped, and placed next to their mother (discharge: 4% vs 6%, 4-5 days: 6.3% vs 9.2%) (8).

Interpretation of findings: SSC

The most recent literature on SSC suggests a myriad of benefits for healthy infants in both developing and developed nations, although most studies were done with a control group of a swaddled infant lying in the bassinet or next to but not in contact with the mother, making it unclear if it is the true skin-to-skin contact or just being in contact with a caregiver that is beneficial. Also, the physiological difference between immediate SSC at the time of birth, with the infant in contact with the mother for all assessments and procedures, and returning the infant to the mother for SSC after assessment (the latter of which occurred in most of the articles reviewed) was not made clear by the studies that were conducted since there were no head-to-head trials comparing these two groups.

Early postpartum SSC increased early IBFAT scores and decreased time to first breastfeeding in most of the studies in this review looking at these topics, but this did not impact breastfeeding exclusivity after discharge in the USA study although it did in the Indian and Japanese studies (7-10). One reason why this may have been the case was that Japan and India both have strong paid maternity leave policies, allowing them to spend more time in SSC with their infants as well as more firmly establish breastfeeding before returning to work. New mothers in the US may feel increased pressure to return to work sooner after delivery, which may have a stronger impact on breastfeeding rates than the presence or absence of early SSC. Additionally, since the Moore study categorized the feeding of bottled breastmilk as not exclusive breastfeeding, this may have lowered exclusive breastfeeding rates at 1 month since many babies in the USA have been introduced to a bottle of pumped milk by this point by maternal preference or necessity. It was also underpowered to detect a small difference in this outcome given the small sample size.

There was substantial evidence in favor of the analgesic effect of SSC for neonates undergoing painful procedures. Multiple studies showed lower scores on validated neonatal pain scales as well as decreased crying times after painful procedures, although not necessarily during the procedure itself, in infants undergoing SSC. However, it is not clear if the benefit was due to physical skin-to-skin contact or the comforting effect of being close to the mother given the control groups utilized. A few studies also demonstrated a smaller increase in heart rate and decrease in oxygen saturation after the intervention, showing that analgesia through SSC may have immediate physiological benefits as well. Additionally, the effect was augmented if the infant was either breastfeeding or had been given oral sucrose prior to stimulus, although the acceptability of oral sucrose in hospitals may be questionable given that it may interrupt early exclusive breastfeeding.

There was less recent data regarding the effect of SSC on thermoregulation, but the reviewed studies suggested that SSC is at least equivalent to radiant rewarming after the first bath and superior to being clothed and/or wrapped in blankets and placed at the mother's side after birth. More notably, one study found that most mothers prefer for their infants to be in SSC for rewarming post-bath rather than under a radiant warmer (19). More research is needed to specifically compare SSC vs radiant rewarming for maintaining temperature for infants immediately after delivery.

Studies looking at other effects suggest that SSC during the 1st 2 hours is important to infant bonding, that other caregivers can administer SSC with similar effects, and that infants in SSC may have less weight loss, possibly due to better breastfeeding and decreased energy loss attempting to thermoregulate. However, more well-conducted studies are needed to substantiate these assertions.

Sudden Unexpected Postnatal Collapse

Included articles

Eight articles on SUPC were included in this review. Two were from France, and one each was from Austria, Canada, Germany, Sweden, USA, and the UK. In contrast with the physiological effects section which was composed of articles from both developed and developing nations, all SUPC articles were from developed nations where mother-baby separation was routine in the past and SSC is making a comeback. Four were composed primarily of case reports and four were epidemiological studies.

Epidemiology

Because definitions of SUPC vary between authors, differing in time periods after delivery, gestational age at birth, the amount of resuscitation required to qualify as an episode of SUPC, and inclusion/exclusion criteria, the published incidence varies widely from 2.6-133/100,000 live births (4). (See Appendix A for breakdown of published incidences and criteria to qualify for SUPC.) Notably, many articles included late preterm infants with gestational age ≥35 weeks as well as cases that only required vigorous stimulation for recovery. Of the six papers that specifically reported SUPC incidences, two defined the relevant time period as the first 24 hours after birth, two as the first two hours, one as the first 12 hours, and one as between 6-100 hours. There were no papers in this review that looked at SUPC after hospital discharge, likely because such events would have been reported as Sudden Infant Death Syndrome (SIDS).

However, despite the widely-varying incidences, it appears that the greatest risk was during the first two hours post birth, especially during the first breastfeeding attempt (2-4,22-28). In one study, it was found that 1/3 of SUPC episodes occurred in the 1^{st} 2 hours after birth, while 1/3 occurred between 2-24 hours, and 1/3 occurred between 1-7 days (2). Another study reported that 73% of SUPC events took place during the 1^{st} 2 hours post birth (28).

Relationship of SSC to SUPC

Not all cases of SUPC occurred while the infant was in SSC, but most published case reports of SUPC reported that the majority of infants experiencing SUPC were in SSC at the time of collapse (2,3,22,23,26,29,30). Data comparing incidence of SUPC in infants in SSC vs in the bassinet is limited, but multiple papers report conflicting statistics. One reported that there was no change in ESUDI (early sudden unexpected death in infancy) in England from 1983-2007 despite increased practice of SSC (22), and another found that, of 26 cases of SUPC, 15 were found in SSC (2).

However, another review found that incidence of SUPC increased from 0.6/1000 to 0.74/1000 in Spain after the introduction of early SSC (2). A Canadian study reported 59 cases, of which 3 were not in SSC with mom at the time of SUPC (30). A nationwide German epidemiological study reported that, of 17 cases, 2 were supine in their own bed at the time of collapse (3), and a similar UK study found that, out of 30 unexplained SUPC cases, 18 were in SSC, 9 were in the mother's arms without SSC, and 3 were supine in a cot (28). However, none of these studies attempted to report a relative risk of SUPC for infants in SSC vs in a bassinet, therefore it is not clear whether SSC is linked with SUPC or if the larger number of infants that experience SUPC when in SSC simply reflects the increasing provision of and time spent in SSC vs conventional care.

Risk factors

The major risk factors reported by most papers were that the infant was in prone positioning at the time of collapse, the mother was primiparous, and that mother and baby had been left alone and unmonitored by healthcare staff (2,4,22,25,28). Prone positioning has previously been implicated as a risk factor for SIDS, which is felt to have a similar pathophysiology to SUPC (25). Primiparous mothers may be less experienced at positioning their babies and in recognizing dangerous situations, increasing the risk of unnoticed neonatal collapse. Mothers are often left unmonitored with their newborn after delivery, presumably to facilitate uninterrupted bonding (28), although there is no current evidence that the unobtrusive presence of healthcare personnel impedes such bonding.

Other risk factors mentioned included maternal obesity (25,29,30), maternal pharmacologic sedation within 8 hours from opiate medication, intrapartum or postpartum magnesium administration, maternal general anesthesia (4,25,29), extreme maternal fatigue (4,25,29), and parental distractions including smartphone use (2,25). However, in most reported cases of SUPC, the mother was awake at the time of collapse, had not been given sedative medication recently, and had reported that their infant was well less than 30 minutes before the incident took place (24), with the median interval in one study between last seeing infant well and finding infant lifeless being 15 minutes (3).

Pathophysiology

The main precipitating factor for SUPC is thought to be acute upper airway obstruction (22). Possible etiologies for this are poor positioning that narrows or blocks the newborn's airway and obstruction of the nares and mouth with the mother's breast or bedding. A triple-risk model developed for SIDS is thought to apply to SUPC as well (25). The components of this model are 1) intrinsic vulnerability, 2) extrinsic risk factor(s), and 3) developmentally-vulnerable time period (22).

For SUPC, it is thought that some newborns may be intrinsically vulnerable, possibly due to a transient hypoxic event ante- or intrapartum, an underlying infection, a cardiorespiratory or metabolic defect (25), or immaturity or underdevelopment of their neural response to hypoxia (22). Although most autopsies in SUPC victims are unrevealing, one study of 10 children who died from ESUDI found a high incidence of leukomalacia in the white matter and brainstem, suggesting that there may have been prenatal ischemic brain insults leading to increased vulnerability (22).

Extrinsic risk factors have been extensively discussed above (see Risk Factors).

The 1st few hours of life are thought to be a developmentally-vulnerable period referred to by many authors as the postnatal adaptation (22). The newborn experiences an initial wave of sympathetic activity after delivery that rapidly dissipates and is followed by a period of diminished responsiveness to external stimuli (3) resulting from increased vagal tone (26). Many parents note that their babies are alert after birth and fall asleep for a long period after the first 30 min-1 hour of life, corresponding to this shift. The highest incidence of SUPC takes place during this period of diminished responsiveness (first 2-4 hours of life). One study found that restart of breathing after hypoxic challenge took longer during this time, and some newborns responded to hypoxia with apnea (4).

Sequelae

It is estimated that about ½ of babies experiencing SUPC will die, and ½ of the survivors will exhibit an abnormal neurological exam at discharge (2). However, many articles reviewed here revealed lower rates of disability and death, although they incorporated events that required only vigorous stimulation or brief PPV for resuscitation. In a large 2009 epidemiological study incorporating every pediatric department in Germany, it was found that, of 17 qualifying cases, 7 died and 6/10 survivors were neurologically abnormal at discharge (3). In a similar nationwide study in the UK, out of 30 cases where no underlying condition was found, 6 died, and 5 of the survivors had an abnormal neurological exam at 1 year ranging from mild global delay to cerebral palsy (28). However, in a Swedish retrospective study, out of 26 SUPC cases, 5 developed hypoxic-ischemic encephalopathy, there were no deaths, and 25 infants were neurologically normal upon discharge (2).

Recommendations for supporting SSC and reducing risk of SUPC

Assessment of the true incidence of SUPC

As mentioned earlier, the definition of SUPC is highly variable between authors, making it difficult to determine the actual incidence and differences between countries. Pejovic and Ferrarello both discussed the difficulty of comparing incidences when the definitions differ and recommended the development of a consensus definition for SUPC (2,25).

Another issue with assessing the true incidence of SUPC is that most reports of SUPC are case reports rather than epidemiological studies. Thach recommended that SUPC cases fall under mandatory reporting to a public health agency as is currently the case for SIDS deaths (29). In Germany, which has a reporting system incorporating every pediatric department nationwide, the authors could calculate an incidence and mortality rate (3). The Andres paper, which analyzed data from voluntary reporting, warned that their reported rates may be lower than actual rates because cases with favorable outcomes may not be reported (26).

Monitoring of dyad by healthcare staff

All the articles included in this review recommended monitoring of the mother-infant dyad by healthcare staff, especially during the first 2 hours of life and for primiparous mothers. However, the frequency, timing, and criteria monitored differed. Since collapse can occur suddenly and without warning, monitoring would need to be continuous to completely prevent deaths (29). This is not logistically feasible from a nursing standpoint at many hospitals, so there have been multiple protocols developed by various institutions for monitoring of infants in SSC that concentrate discontinuous monitoring when the risk of SUPC is highest, similar to monitoring that takes place in other hospital settings such as more frequent vital checks for postoperative patients.

One tool, the RAPP assessment, was designed for nurses to observe and record the infant’s respiratory status, activity, perfusion, and position (25). (RAPP assessment chart criteria can be viewed in Appendix F (31)). The Safe Neonatal Transitions Pathway developed by Pennsylvania Hospital in Philadelphia recommends that nurses routinely perform APGAR assessments at 1 and 5 minutes and newborn assessments, including vital signs (heart rate, respiratory rate, and temperature) and RAPP assessment at 10, 20, 40, and 60 minutes of life and every 30 minutes thereafter until up to 4 hours of life (25). While the RAPP assessment is thought to take no longer than an APGAR score and can be easily incorporated into the electronic medical record, the feasibility and efficacy of it in preventing SUPC has not yet been proven through multicenter studies (27).

Another tool developed by Davanzo calls for assessment at 10, 30, 60, 90, and 120 min of life of the infant's position, perfusion and respiration, and whether mother and baby are supervised (27). (Checklist can be viewed in Appendix G). This protocol has been in place in an Italian maternity hospital since February 2014 and has reportedly detected 2 cases of cyanosis out of 916 babies, although it has not been rigorously studied in other settings (27). However, it recommends that, if supervision is not possible and parental reliability is in question, the newborn be admitted to the newborn nursery, a suggestion that may or may not be acceptable to the parents and eliminates the possibility of SSC.

Other articles did not present a specific protocol, but called for checks of infant condition by nursing staff or midwives at frequent, specific time intervals especially during 0-3 hours postpartum (2,24). Many authors suggested that the 1st breastfeeding attempt was a particularly vulnerable time and therefore that all breastfeeding attempts within the first two hours of life should be observed by healthcare staff (2,4,25-27). There were no protocols presented for monitoring of infants greater than four hours old, although the AAP recommended "standardized methods and procedures" for providing SSC and monitoring and documentation on the postpartum ward of infant's position, perfusion, and respiratory status (4).

Monitoring by friends and family

Monitoring by mothers and their family and friends has been suggested to augment but not replace staff monitoring (4). In the German study reporting on 17 SUPC cases, seven were discovered by a healthcare professional despite the mother being awake, six were discovered by the mother with four discovered after she woke up from a nap, three were discovered by the father, and one was discovered by a maternal roommate (3).

One suggestion presented in two different articles was the promotion of professional labor support, such as a doula. Professional labor support has been demonstrated to both decrease the use of labor medications and slightly shorten labor (25). Since both sedating medications and maternal exhaustion may be linked to SUPC (25), and trained support could be recruited postpartum to act as another set of eyes, doulas could support nurses in monitoring neonates during the most vulnerable time.

Parental education

Education of parents was discussed in three articles and included topics such as the risk of SUPC during SSC, how to assess their infant, the importance of avoiding distractions such as smartphones, and how to avoid high-risk situations such as falling asleep with the baby in SSC. Thach suggested that expectant parents be taught to assess their infant's breathing, skin color, and response to stimuli (29). The AAP recommends that staff educate mothers and support persons about the risk of the mother falling asleep during breastfeeding or holding the baby in SSC and the need to place the newborn on a separate sleep surface when this occurs (4). Ferrarello advised nurses to provide anticipatory guidance to new parents regarding newborn behavior and appearance as well as the importance of watching their newborn immediately postpartum and waiting until later to use smartphones (25). Pejovic called for "delivery of oral and written information to parents" that was not specified in the paper, but reported in their review that introducing parental education and supervision did not reduce the incidence of SUPC but did reduce severity of outcomes (2).

Sufficient room lighting

In many reported SUPC cases, the room was dark or dimly lit, hindering adequate assessment of the infant's wellbeing (29). Both Thach and the AAP discussed the importance of having sufficient room lighting to allow for full assessment of the infant's appearance and color (4,29). However, there have been no studies at this time that look at whether lighting makes a difference in SSC safety.

Maternal and infant positioning

Since most SUPC cases are thought to result from a neonate's inappropriate response to acute upper airway obstruction (22), multiple articles discussed the danger of improper positioning and protocols for ensuring proper positioning (2,4,25,27). Pejovic mentioned that an "asphyxiating position" is a strong risk factor for SUPC, and for the 14 cases where positioning information was available, 10 were found with the mother's breast covering the infant's face (2). Davanzo's checklist includes "infant positioned with visible and unobstructed mouth and nose" and reported 2 cases of cyanosis out of 916 babies monitored, both of which had obstruction of the mouth and nose and whose cyanosis resolved upon resolution of the obstruction (27).

The AAP recommends assessment of the infant's position during routine nurse check-ins (4). Ludington-Hoe describes the components of safe SSC positioning as follows (bolded are incorporated into RAPP assessment) (31):

1. Infant's face visible
2. Infant's head in sniffing position
3. **Infant's nose and mouth uncovered**
4. **Infant's head turned to one side**
5. **Infant's neck straight, not bent**
6. Infant's shoulders and chest face mother
7. Infant's legs flexed
8. Infant's back covered with blankets
9. Mother-infant dyad continuously monitored on L&D and regularly on postpartum unit
10. When mother desires to sleep, infant placed on bassinet or with another support person who is awake and alert

Although multiple articles discuss infant positioning, Ferrarello addresses maternal positioning as well, recommending elevation of the maternal bed to an angle from 35-80 degrees rather than fully supine, which may decrease the risk of the infant's face becoming obstructed by the maternal breast (25).

Electronic monitoring

Many articles briefly discussed the potential use of continuous electronic monitoring of SpO2 and heart rate of neonates using pulse oximetry. Thach mentioned the possibility of using an electronic monitor with alarms to the nursing station to avoid disturbing parents (29), while Andres reported that there have been recent tests of wireless, wearable pulse ox systems for surveillance of infants at risk of ALTE after delivery (26). These tests were conducted using a wireless "bootie", and the authors concluded that the device provided reliable pulse ox measurements and information on the infant's movement and position and could be used for monitoring during infant SSC after delivery (32).

However, other authors have raised questions about the necessity of routine electronic monitoring. Poets felt that electronic monitoring may have avoided some SUPCs, but that routine electronic surveillance of thousands of healthy neonates was unlikely to be cost-effective (3). Pejovic and the AAP reported that there had been no studies showing evidence of safety improvement and that such studies were necessary before implementing universal monitoring (2,4). Davanzo reported concerns that such a device may interfere with bonding and the pulse oximeter reading may be influenced by other factors such as timing of cord clamping (27).

Interpretation of findings and limitations of SUPC research

For SUPC and prevention of adverse events, there is a strong consensus on the major risk factors, pathophysiology, and the need for extra monitoring of mother and baby by healthcare staff, especially during the first few hours of life. However, minor risk factors such as obesity, maternal sedation/exhaustion, anesthesia, etc., have been suggested but not formally reported. Also, the exact details of the nature and timing of the extra monitoring is not established, and there have been few studies conducted on the efficacy and feasibility of various monitoring recommendations and protocols. Other recommendations such as monitoring by family and friends, parental education, and regimented maternal and infant positioning, are seemingly common-sense but have not been shown formally to alter the risk of SUPC.

Major limitations of SUPC research are that most of the literature is based on case reports, which may serve to increase fear without providing context as to the rarity of the event, and the lack of evidence surrounding much of the conjecture around the risk factors, pathophysiology, and prevention measures for SUPC. There have been no high quality RCTs or observational studies demonstrating that specific prevention measures are beneficial in reducing the risk of SUPC during SSC, so this section relies largely on expert opinion and recommendations from leading manuscripts in the field.

Additionally, it is difficult to ascertain the true rate of SUPC in different hospitals and countries due to differences in reporting requirements and even the definition of SUPC itself. This also makes inter-hospital and inter-country comparison, which might provide evidence for risk factors and the efficacy of various interventions, impractical.

Recommendations and significance for MCH

Most of the studies reviewed had infants undergoing some combination of drying, physical examination, and initial procedures such as bathing, suctioning, and vitamin K injection under a radiant warmer before being returned to their mothers, and this variation makes it difficult to establish the benefits of continuous, uninterrupted SSC as recommended by the WHO. Ideally, it would be beneficial to study infants who were returned to their mothers after a few minutes of separation vs those who were immediately placed and left SSC, with all procedures done during SSC with the mother. Additionally, studies with clothed or swaddled infants in SSC position or in a parent's arms as the control could also be conducted to determine if it is proximity to the caregiver or the actual skin-to-skin contact that benefits the neonate.

Given consistent findings across the 8 studies examined that SSC is associated with decreased pain expression in infants (the effect with the largest body of evidence in this review), consideration should be given to routinely recommending SSC during painful procedures, preferably in conjunction with breastfeeding for breastfed infants or oral sucrose for those infants that are not being breastfed. Additional studies would be beneficial to more clearly define whether longer SSC is associated with greater degree of or prolonged analgesia.

The evidence for improved breastfeeding initiation and duration in SSC infants was positive, but not completely consistent among all studies. The field would benefit from more studies with later IBFAT scores obtained for infants that received SSC care at birth vs conventional care, like the Thukral study, to allow for blinding of group status for IBFAT scorers and to assess whether the early benefits for breastfeeding behavior persist over time. Also, it would be interesting to conduct follow-up studies to observe if early SSC affects the percentage of mothers that achieve their breastfeeding goals past 4-6 weeks.

The most recent evidence for neonatal thermoregulation was sparse, consisting of only three studies. Also, none of the studies reviewed specifically compared SSC vs radiant warmer after delivery, which are the most common choices available in developed nations. Further studies comparing these two options would be beneficial to determine if SSC is superior to or at least equivalent to a radiant warmer for maintaining an appropriate body temperature after birth.

SUPC prevention: future directions

Much needs to be done in the world of SUPC prevention. First, a consensus definition of SUPC is needed. Once one is adopted, national public health agencies could consider making SUPC a mandatorily reportable condition. There is precedent for similar mandatory reporting in the case of SIDS in the US and other countries, and the Child Fatality Task Force investigation model in the US demonstrates how investigation of details surrounding infant death can be helpful in identifying risk and protective factors.

Experiences of hospitals that have successfully and safely implemented SSC suggest that it may be beneficial to develop protocols for monitoring of mother and newborn based on their own staffing and capabilities. These protocols can be based on the RAPP assessment or the assessment presented in Davanzo, but may include newborn vitals and assessment of position and cardiorespiratory status of the infant with monitoring concentrated in the first 4 hours after birth. These protocols are as important as other protocols for other patients needing increased monitoring, such as post-operative patients, and corrective measures should be initiated if the situation is found to be unsafe. Each protocol can be piloted by healthcare staff who give feedback and suggestions for improvements using QI tools such as Plan-Do-Study-Act (PDSA) cycles to facilitate rapid adjustment. Along with mandatory data collection and reporting, this will assist the development of "optimal" protocols that can be adopted and adjusted by other facilities.

There were many other suggestions given for SUPC prevention but very little evidence present for those suggestions. It would likely be difficult to perform a prospective cohort study or randomized controlled trial of these recommendations due to both the rarity of SUPC and the ethical implications of randomizing mother-baby dyads to practices considered unsafe, but it may be possible to perform case-control analysis of SUPC cases using reporting data to determine if there is evidence for some of the different interventions suggested by experts.

Additionally, it is prudent to carefully consider the potential role of electronic monitoring. With the strong push for immediate SSC and recent proliferation of both hospital and consumer-grade monitoring devices marketed to reduce the risk of SIDS (32,33), these devices may someday be implemented in hospitals experiencing staff shortages to assist nurses despite the lack of evidence that such devices could safely replace or supplement staff nurses. More widespread availability of affordable CR monitoring devices raise the question of whether such devices might be useful in hospitals in the future after rigorous testing of their efficacy.

Conclusions

Early postpartum skin to skin care is an evidence-based practice with benefits for breastfeeding initiation and continuation, neonatal pain relief, and temperature regulation, and other effects in healthy term infants, and should be offered to all medically-stable mothers of such infants regardless of intended feeding method. It can potentially be combined with other interventions such as breastfeeding or oral sucrose for a synergistic effect prior to painful stimulus. Future studies as described previously can be conducted to increase the body of evidence for these effects and to determine which protocols safely maximize these benefits.

Though SSC has documented benefits and little evidence of harm, SUPC is a rare and potentially devastating event that can occur with or without SSC and requires vigilance and attention. To reduce the risk, mothers and infants require monitoring by healthcare professionals, especially in the first four hours after delivery and during the first breastfeeding attempt. High-quality studies need to be conducted on various surveillance protocols as well as other recommendations proposed. Additionally, a formal definition of SUPC as well as consideration for mandatory reporting of SUPC cases in each country may be considered to assess the true incidence of SUPC in each country as well as risk and protective factors.

As early SSC, recommended by the WHO, the AAP, and other agencies for its physiological effects, continues in developing countries and is reincorporated into standard maternity care practices in developed countries, there is a need for rigorous studies on the conditions that allow for maximal benefit for both mother and baby while minimizing the risk of SUPC.

References

(1) Moore ER, Anderson GC, Bergman N, Dowswell T. Early skin-to-skin contact for mothers and their healthy newborn infants. Cochourane Database Syst Rev 2012 May 16;(5):CD003519. doi(5):CD003519.

(2) Pejovic NJ, Herlenius E. Unexpected collapse of healthy newborn infants: risk factors, supervision and hypothermia treatment. Acta Paediatr 2013 Jul;102(7):680-688.

(3) Poets A, Steinfeldt R, Poets CF. Sudden deaths and severe apparent life-threatening events in term infants within 24 hours of birth. Pediatrics 2011 Apr;127(4):e869-73.

(4) Feldman-Winter L, Goldsmith JP, COMMITTEE ON FETUS AND NEWBORN, TASK FORCE ON SUDDEN INFANT DEATH SYNDROME. Safe Sleep and Skin-to-Skin Care in the Neonatal Period for Healthy Term Newborns. Pediatrics 2016 Sep;138(3):10.1542/peds.2016-1889. Epub 2016 Aug 22.

(5) Vallenas C, Savage F. Evidence for the ten steps to successful breastfeeding. World Health Organization 1998:http://www.who.int/nutrition/publications/evidence_ten_step_eng.pdf.

(6) Beiranvand S, Valizadeh F, Hosseinabadi R, Pournia Y. The Effects of Skin-to-Skin Contact on Temperature and Breastfeeding Successfulness in Full-Term Newborns after Cesarean Delivery. Int J Pediatr 2014;2014:846486.

(7) Moore ER, Anderson GC. Randomized controlled trial of very early mother-infant skin-to-skin contact and breastfeeding status. J Midwifery Womens Health 2007 Mar-Apr;52(2):116-125.

(8) Srivastava S, Gupta A, Bhatnagar A, Dutta S. Effect of very early skin to skin contact on success at breastfeeding and preventing early hypothermia in neonates. Indian J Public Health 2014 Jan-Mar;58(1):22-26.

(9) Thukral A, Sankar MJ, Agarwal R, Gupta N, Deorari AK, Paul VK. Early skin-to-skin contact and breast-feeding behavior in term neonates: a randomized controlled trial. Neonatology 2012;102(2):114-119.

(10) Suzuki S. Effect of early skin-to-skin contact on breast-feeding. J Obstet Gynaecol 2013 Oct;33(7):695-696.

(11) Chermont AG, Falcao LF, de Souza Silva EH, de Cassia Xavier Balda R, Guinsburg R. Skin-to-skin contact and/or oral 25% dextrose for procedural pain relief for term newborn infants. Pediatrics 2009 Dec;124(6):e1101-7.

(12) Kostandy R, Anderson GC, Good M. Skin-to-skin contact diminishes pain from hepatitis B vaccine injection in healthy full-term neonates. Neonatal Netw 2013 Jul-Aug;32(4):274-280.

(13) Fallah R, Naserzadeh N, Ferdosian F, Binesh F. Comparison of effect of kangaroo mother care, breastfeeding and swaddling on Bacillus Calmette-Guerin vaccination pain score in healthy term neonates by a clinical trial. J Matern Fetal Neonatal Med 2016 Jul 20:1-4.

(14) Saeidi R, Asnaashari Z, Amirnejad M, Esmaeili H, Robatsangi MG. Use of "kangaroo care" to alleviate the intensity of vaccination pain in newborns. Iran J Pediatr 2011 Mar;21(1):99-102.

(15) Kashaninia Z, Sajedi F, Rahgozar M, Noghabi FA. The effect of Kangaroo Care on behavioral responses to pain of an intramuscular injection in neonates. J Spec Pediatr Nurs 2008 Oct;13(4):275-280.

(16) Seo YS, Lee J, Ahn HY. Effects of Kangaroo Care on Neonatal Pain in South Korea. J Trop Pediatr 2016 Jun;62(3):246-249.

(17) Marin Gabriel MA, del Rey Hurtado de Mendoza,B., Jimenez Figueroa L, Medina V, Iglesias Fernandez B, Vazquez Rodriguez M, et al. Analgesia with breastfeeding in addition to skin-to-skin contact during heel prick. Arch Dis Child Fetal Neonatal Ed 2013 Nov;98(6):F499-503.

(18) Okan F, Ozdil A, Bulbul A, Yapici Z, Nuhoglu A. Analgesic effects of skin-to-skin contact and breastfeeding in procedural pain in healthy term neonates. Ann Trop Paediatr 2010;30(2):119-128.

(19) George S, Phillips K, Mallory S, Holmquistova I, Hare R, Allen S, et al. A pragmatic descriptive study of rewarming the newborn after the first bath. J Obstet Gynecol Neonatal Nurs 2015 Mar-Apr;44(2):203-209.

(20) Bystrova K, Ivanova V, Edhborg M, Matthiesen AS, Ransjo-Arvidson AB, Mukhamedrakhimov R, et al. Early contact versus separation: effects on mother-infant interaction one year later. Birth 2009 Jun;36(2):97-109.

(21) Erlandsson K, Dsilna A, Fagerberg I, Christensson K. Skin-to-skin care with the father after cesarean birth and its effect on newborn crying and prefeeding behavior. Birth 2007 Jun;34(2):105-114.

(22) Gnigler M, Ralser E, Karall D, Reiter G, Kiechl-Kohlendorfer U. Early sudden unexpected death in infancy (ESUDI)--three case reports and review of the literature. Acta Paediatr 2013 May;102(5):e235-8.

(23) Dageville C, Pignol J, De Smet S. Very early neonatal apparent life-threatening events and sudden unexpected deaths: incidence and risk factors. Acta Paediatr 2008 Jul;97(7):866-869.

(24) Fleming PJ. Unexpected collapse of apparently healthy newborn infants: the benefits and potential risks of skin-to-skin contact. Arch Dis Child Fetal Neonatal Ed 2012 Jan;97(1):F2-3.

(25) Ferrarello D, Carmichael T. Sudden Unexpected Postnatal Collapse of the Newborn. Nurs Womens Health 2016 Jun-Jul;20(3):268-275.

(26) Andres V, Garcia P, Rimet Y, Nicaise C, Simeoni U. Apparent life-threatening events in presumably healthy newborns during early skin-to-skin contact. Pediatrics 2011 Apr;127(4):e1073-6.

(27) Davanzo R, De Cunto A, Paviotti G, Travan L, Inglese S, Brovedani P, et al. Making the first days of life safer: preventing sudden unexpected postnatal collapse while promoting breastfeeding. J Hum Lact 2015 Feb;31(1):47-52.

(28) Becher JC, Bhushan SS, Lyon AJ. Unexpected collapse in apparently healthy newborns--a prospective national study of a missing cohort of neonatal deaths and near-death events. Arch Dis Child Fetal Neonatal Ed 2012 Jan;97(1):F30-4.

(29) Thach BT. Deaths and near deaths of healthy newborn infants while bed sharing on maternity wards. J Perinatol 2014 Apr;34(4):275-279.

(30) Schrewe B, Janvier A, Barrington K. Life-threatening event during skin-to-skin contact in the delivery room. BMJ Case Rep 2010 Dec 29;2010:10.1136/bcr.11.2010.3475.

(31) Ludington-Hoe S, Morgan K. Infant Assessment and Reduction of Sudden Unexpected Postnatal Collapse Risk During Skin-to-Skin Contact. Newborn and Infant Nursing Reviews 2014 2016/11;14(1):28-33.

(32) Rimet Y, Brusquet Y, Ronayette D, Dageville C, Lubrano M, Mallet E, et al. Surveillance of infants at risk of apparent life threatening events (ALTE) with the BBA bootee: a wearable multiparameter monitor. Conf Proc IEEE Eng Med Biol Soc 2007;2007:4997-5000.

(33) Owlet. 2016; Available at: http://www.owletcare.com/.

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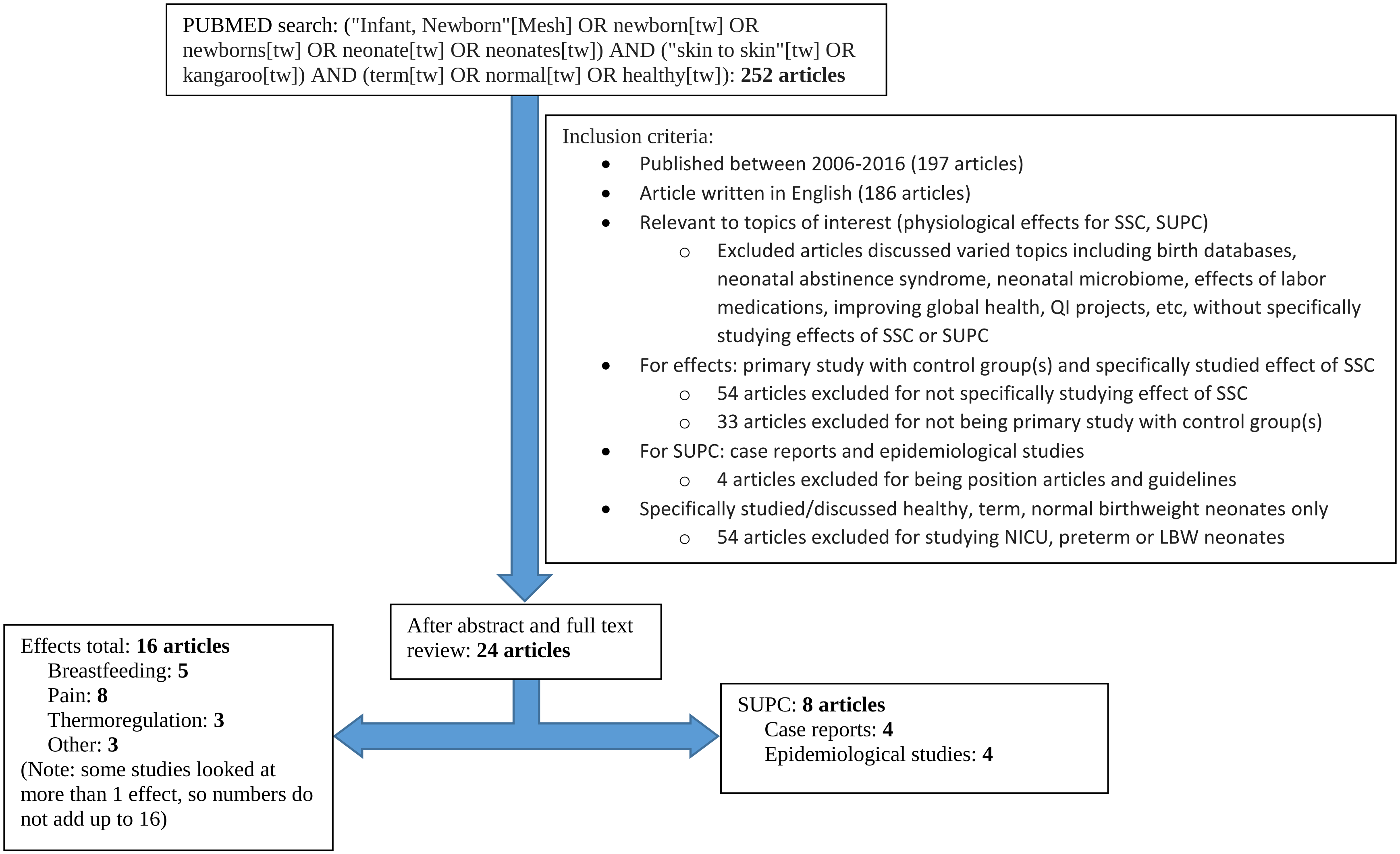
Appendix A. Information about SUPC study articles

Primary author Study type	Location of reported statistic	Year(s)	Definition	Incidence Mortality	Other notes
Andres Case reports	West Provence-Alpes, Cote d'Azur, France	2004-2007	"Healthy" infant ≤2 hrs of life Cardiorespiratory failure requiring from vigorous stimulation to intubation and mechanical ventilation	6 cases, 3 deaths Incidence 0.034/1000 Mortality 0.017/1000	All cases had APGARs 10/10, earliest GA at birth was 36w5d
Becher Prospective national study	UK	Nov 1, 2008-Nov 30, 2009	≥ 37w GA 5 min APGAR ≥ 8 Collapsed within 12 hrs of birth requiring PPV and either died or required NICU admission	45 cases, 12 deaths Incidence 0.05/1000 Mortality 0.013/1000	15 cases where underlying etiology for collapse was found
Dageville Prospective study	Provence-Alpes-Cote d'Azur, France	May 2, 2006-May 1, 2007	Healthy neonates ≥36w GA ≤2 hrs of life Marked pallor/cyanosis, major hypotonia or stiffness with no apparent movement, requiring at least vigorous stimulation and CPR if necessary Secondary transfer to NICU if above maneuvers successful Lack of evidence of any underlying condition	62,968 live births 2 cases, 0 deaths Incidence 0.032/1000	

Gnigler Review	Sweden	1985	Full-term healthy neonates 6-100 hrs of life Sudden cardiovascular collapse-> death	Incidence/ mortality 0.12/1000	Included cases where underlying etiology was found (infection, anemia, etc)
Pejovic Retrospective chart review	Stockholm University Hospitals, Sweden	Jan 1, 2010- June 6, 2012	>35w GA 10 min APGAR ≥ 8 ≤ 24 hrs after birth Acute cyanosis/pallor and unconsciousness requiring vigorous stimulation, CPAP, bag ventilation, intubation, and/or cardiac compressions	68,364 live births 26 cases, 0 deaths Incidence 0.38/1000	12 cases where plausible etiology for collapse was found
Poets Prospective epidemiological study	Germany (nationwide)	2009	≥ 37w GA 10 min APGAR ≥ 8 ≤ 24 hrs after birth Acute cyanosis/pallor and unconsciousness requiring bagging, intubation, and/or cardiac compressions	17 cases, 7 deaths Incidence 0.026/1000 Mortality 0.011/1000	≥ 95% capture rate estimated 9/17 within 1st 2 hrs of life
Schrewe Case report + Pubmed lit search	University of Montreal, Canada	2010	"Apneic episode requiring resuscitation and intensive care support in a term baby who appears otherwise healthy at birth during a period of early skin to skin care by the mother" during the first 12 hours of life	59 cases, 34 deaths No incidence or mortality reported	
Thach Case studies	USA	2014	"Death or near death of healthy infant occurring during SSC within the first 24 hrs of birth"	18 cases, 15 deaths	Cases obtained from request to National Association of Medical examiners on deaths and near deaths

Appendix B. Flowchart of search and paper selection



Appendix C. SSC effects articles chart (RCT=randomized controlled trial, BF=breastfeeding, SpO2=oxygen saturation)

Primary Author	Country	Study type	Effect(s) studied	Intervention	Control	Other notes
Beiranvand	Iran	RCT	BF, temp	SSC for 1 hour when mother out of OR	Dressed and placed in cot	After elective cesarean under spinal anesthesia BF success assessed via IBAT
Bystrova	Russia	RCT	Bonding 1 year after delivery	I: SSC + rooming in postpartum II: Dressed and placed in mother's arms + rooming in postpartum	III: Nursery both after birth and postpartum IV: Nursery after birth, but roomed in postpartum	All infants initially subject to 25 min of compulsory delivery ward routines (cord clamping, examination, bath, eye ointment) before initiation of intervention
Chermont	Brazil	RCT	Pain	II: Oral 25% dextrose 2 minutes before injection III: Oral sterile water + SSC initiated 2 min before injection and persisting through procedure IV: Oral dextrose + SSC	I: Oral sterile water with infant supine in crib	Hepatitis B vaccine at 12-72 hrs of life used for pain stimulus Rating done via neonatal facial coding system (NFCS), neonatal infant pain scale (NIPS), and premature infant pain profile (PIPP)
Erlandsson	Sweden	RCT	Crying	SSC on father's chest while father seated in armchair	Wrapped in towels in cot next to father, father could console freely but not pick up child	SSC with father after elective cesarean under spinal anesthesia All infants placed on mother's chest wrapped in towels for 5-10 min in OR

Fallah	Iran	RCT	Pain	I: BF 2 min before, during, and 1 min after stimulus II: SSC 10 min before, during, and 1 min after stimulus	III: Swaddled 10 min before, during, and 1 min after stimulus	BCG vaccine during 1st day of life used as pain stimulus Assessment done via NIPS
George	USA	Prospective cohort	Temp	SSC after 1st bath	Radiant warmer after 1st bath	Originally intended as pragmatic controlled trial, but stopped early after 96/first 100 mothers chose SSC over radiant warmer
Kashaninia	Iran	RCT	Pain	SSC for 10 min before injection Mothers place hands over blankets on baby's back, asked not to comfort baby in any way	Left for 10 minutes in quiet nursery	Vitamin K injection at 2 hours of life as pain stimulus Infants were not fed prior to injection Assessment done via NIPS
Kostandy	USA	RCT	Pain	SSC on mother's chest for 15-20 minutes before, during, and 5 min after injection, mother permitted to comfort neonate	Supine in bassinet in nursery	Hepatitis B vaccine before 48 hours of life as pain stimulus Assessment done via recorded cry time, heart rate, Anderson Behavioral State Scale (ABSS)
Marin Gabriel	Spain	RCT	Pain	I: BF+SSC starting ≥5 min before and during heel lance II: SSC started ≥5 min before heel lance + 24% oral sucrose 2 min before heel lance	III: SSC only before and during heel lance IV: Sucrose only to neonates supine in cot in presence of mother	Heel lance for metabolic screening at ≥24 hrs used as pain stimulus Assessment done via recorded crying time, heart rate, NIPS

Moore	USA	RCT	BF	SSC immediately after birth, then taken to radiant warmer after cord cutting for same procedures as control. SSC reinitiated during laceration repair after routine infant procedures completed	Shown to mother briefly after delivery, then placed under radiant warmer for PE, suction, Vitamin K and erythromycin. Infant swaddled in 2 blankets and returned to mother after her laceration repair. Infant transferred to transition nursery as soon as 1hr postbirth to free labor beds	Primip dyads only Assessment by IBAT and time to effective breastfeeding (1st of 3 consecutive scores of 10-12 on IBAT), mother's reported breastfeeding problems by Breastfeeding Experience Scale (BES). phone questionnaire of breastfeeding status/exclusivity at 30 days postpartum
Okan	Turkey	RCT	Pain	I: BF + SSC for 15 min prior to heel lance II: SSC for 15 min prior to heel lance Both allowed to comfort infants as desired	III: Breastfed and burped, then taken to nursery, wrapped in blankets, and placed supine on exam table. Infants not touched or spoken to other than on assigned foot	Heel lance for metabolic screening as painful stimulus Assessment via heart rate, SpO2, duration of crying, NFCS viewed on videotape
Saeidi	Iran	RCT	Pain	SSC for 30 min prior to, during, and 3 min after injection	Wrapped in blanket and placed near mother's bed	Vaccination as painful stimulus Assessment via NIPS, heart rate, SpO2, crying duration

Seo	South Korea	RCT	Pain	SSC 10 minutes before, during, and 3 min after sampling	Not specified	Heel lance for metabolic study as painful stimulus Assessment done by heart rate, SpO2, and PIPP
Srivastava	India	RCT	BF, temp, neonatal weight loss	SSC initiated within 30 min of birth after weighing and declaration of sex for at least 2 hours	After drying and weighing, infant clothed, wrapped in sheet and blanket, and placed next to mother	Axillary temperature taken at beginning of intervention after 2 hours, BF assessment done via IBAT, exclusive BF rates at day 4-5 and 6 weeks, and weight loss at discharge and 4-5 days
Suzuki	Japan	Prospective cohort	BF	Early SSC (not specified)	No early SSC (not specified)	Primip dyads only Assessed exclusive BF rates at 1 month
Thukral	India	RCT	BF	SSC immediately after birth for 2 hours	Kept by mother's side without SSC	No infant received SSC at any other point during hospital stay Assessment via IBAT at 48 hours, exclusive BF rates at 48 hrs and 6 weeks

Appendix D: Infant Breastfeeding Assessment Tool (IBFAT) (Matthews, 1988)

Criterion	Grading			
	3	2	1	0
Readiness	Starts to feed readily without effort	Needs mild stimulation to begin feeding	Needs more stimulation to rouse and begin feeding	Can’t be aroused
Rooting	Roots effective immediately	Needs coaxing, prompting or encouragement	Roots poorly even with coaxing	No attempt to root
Latching	Feeds immediately	Takes 3-10 min to start	Takes >10 min to start	No feed
Sucking	Sucks well on both breasts	Sucks on and off but needs encouragement	Weak suck, sucks on and off for short periods	No sucking

Appendix E : Neonatal Facial Coding System (NFCS), Neonatal Infant Pain Scale (NIPS), Premature Infant Pain Profile (PIPS), and Anderson Behavioral State Scale (ABSS) criteria

Scale	Criteria	Grading
NFCS (Grunau et al, 1987)	Brow bulge, eye squeeze, deepening of nasolabial furrow, open lips, mouth stretch, taut tongue, tongue protrusion, chin quiver	+1 for each criterion present, ≥3 indicates pain
NIPS (Lawrence et al, 1993)	Facial Expression: 0= relaxed muscles; 1= grimace Cry: 0= no cry; 1= whimper; 2= crying Breathing pattern: 0= relaxed, regular pattern; 1= unusual pattern for infant Arms: 0= relaxed; 1= flexed/extended Legs: 0:= relaxed; 1= flexed/extended State of arousal: 0= peacefully sleeping/awake; 1= fussy	<4 indicates no-mild pain ≥4 indicates moderate-severe pain
PIPP (Stevens et al, 1996)-adapted for term infants only	Behavioral State: 0= active/awake; 1= quiet/awake; 2= active/asleep; 3= quiet/asleep HR increase from baseline: 0= 0-4 bpm; 1= 5-14 bpm; 2= 15-24 bpm; 3= ≥25 bpm SpO2 decrease from baseline: 0= 0-2.4%; 1= 2.5-4.9%; 2= 5-7.4%; 3= ≥7.5% Brow bulge: 0= none; 1= minimal; 2= moderate; 3= maximal Eye squeeze: 0= none; 1= minimal; 2= moderate; 3= maximal Nasolabial furrow: 0= none; 1= minimal; 2= moderate; 3= maximal	≤6: no-minimal pain 7-12: mild pain-nonpharmaceutical therapy indicated ≥12: moderate-severe pain-pharmaceutical therapy indicated
ABSS (Gill et al, 1988)	1= regular quiet sleep; 2= irregular sleep; 3= active sleep 4= very active sleep; 5= drowsy; 6= alert inactivity 7= quiet awake; 8= active awake; 9= very active awake 10= fussing; 11= crying, 12= hard crying	10-12 represents infant in pain

Appendix F. RAPP assessment (From Ludington-Hoe et al, 2014). Red shaded boxes indicate concerning findings that require further assessment.

Criteria Birth time_______ Into SSC_______	Date____ Time____	Date____ Time____	Date____ Time____	Date____ Time____	Date____ Time____	Date____ Time____
Respirations						
Easy						
Grunting/Flaring						
Retractions						
Tachypneic						
Activity						
Sleep						
Quiet Alert						
Active alert						
Crying						
Breastfeeding						
Non-responsive						
Perfusion						
Pink						
Acrocyanosis						
Pale						
Dusky						
Position/Tone						
Head turned to one side						
Neck straight						
Nares/mouth visible						
Well flexed						
Some flexion						
Limp/flaccid						
No recoil						
RN Action*						
Continue SSC						
Stop SSC; to Radiant Warmer						
Time KC ends						
Duration of SSC **____________	RN____	RN____	RN____	RN____	RN____	RN____

Appendix G. Checklist (From Davanzo et al, 2015).

Family Name____________ Name____________ Date of Birth___________ Hour of Birth_____:_____	Time after Birth				
Parameters to be Assessed or Events to be Registered	10 min[a]	30 min	60 min	90 min	120 min
1. Infant positioned with visible and unobstructed mouth and nose (Yes/No)					
2. Pink color (skin and/or mucous membranes) (Yes/No)					
3. Normal breathing (no retractions or grunting or flaring of the nares) (Yes/No)					
4. Normal respiratory rate: 30-60 breaths/min (Yes/No)					
5. Normal SpO_2: > 90% (if deemed necessary) (Yes/No)					
6. Subaxillary temperature at 60 and 120 minutes after birth (Normal range: 36.5°C-37.5°C)					
7. Mother never left alone with her infant (Yes/No)					
First breastfeeding attempt (time)					
Comments					