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Increase in Oxytocin From Skin-to-Skin Contact Enhances Development of Parent–Infant Relationship

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Abstract

Objective: To examine changes that occur in infant and parent salivary oxytocin (OT) and salivary cortisol (SC) levels during skin-to-skin contact (SSC) and whether SSC alleviates parental stress and anxiety while also supporting mother–father–infant relationships. **Methods:** This randomized crossover study was conducted in the neonatal intensive care unit (NICU) with a sample of 28 stable preterm infants and their parents. Saliva samples were collected from infants, mothers, and fathers on Days 1 and 2 (1/parent) for OT and cortisol measurement pre-SSC, during a 60-min SSC session, and a 45-min post-SSC. Parental anxiety was measured at the same time points. Parent–infant interaction was examined prior to discharge on Day 3 via video for synchrony and responsiveness using Dyadic Mutuality Coding. **Results:** Salivary OT levels increased significantly during SSC for mothers ($p < .001$), fathers ($p < .002$), and infants ($p < .002$). Infant SC levels decreased significantly ($p < .001$) during SSC as compared to before and after SSC. Parent anxiety scores were significantly related to parent OT and SC levels. Parents with higher OT levels exhibited more synchrony and responsiveness ($p < .001$) in their infant interactions. **Conclusion**: This study addresses a gap in understanding the mechanisms linking parent–infant contact to biobehavioral responses. SSC activated OT release and decreased infant SC levels. Facilitation of SSC may be an effective intervention to reduce parent and infant stress in the NICU. Findings advance the exploration of OT as a potential moderator for improving responsiveness and synchrony in parent–infant interactions.

Keywords

skin-to-skin contact, oxytocin, premature infant, kangaroo care

The neonatal intensive care unit (NICU) environment is often a stark contrast to the expectations parents have for their infants' first days and weeks and can induce parental stress and anxiety that have lifelong effects. Fundamental to the infant's developmental trajectory is early parent–infant contact. Maternal touch, especially during skin-to-skin contact (SSC), has the potential to mitigate some of the adverse consequences of prematurity. SSC is an evidence-based holding strategy that increases parental proximity and provides a continuous interactive environment known to enhance infant physiologic stability and affective closeness within the parent–infant dyad (Ludington-Hoe, 2011; Mori, Khanna, Pledge, & Nakayama, 2010).

SSC improves infant autonomic regulation, as evidenced by a steadier heart rate and improved respiratory status and temperature regulation compared to routine caregiving provided in an incubator (Cong, Ludington-Hoe, McCain, & Fu, 2009). Additional benefits of SSC include improved brain development as well as better motor and mental development (Feldman & Eidelman, 2003; Ferber & Makhoul, 2004). Investigators have reported demonstrated behavioral responses, such as improved state regulation and motor modulation, immediately following even short periods of SSC (Ferber & Makhoul, 2004). In addition, researchers have reported biobehavioral

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responses to SSC, including changes in cortisol level and improved maternal–infant coregulation (Neu & Laudenslager, 2011; Neu, Laudenslager, & Robinson, 2009; Neu & Robinson, 2010). However, the biological mechanisms affected by SSC, including the oxytocin (OT) system, have rarely been studied.

Mothers of preterm infants are more likely to have difficulty with attachment than mothers of full-term infants (Lee, Macbeth, Pagani, & Young, 2009; Poehlmann & Fiese, 2001). Researchers have attributed this difficulty to decreased synchrony or responsiveness in parent–infant interactions as well as the increased subtlety of premature infants' behavioral cues, which can make them difficult to interpret (Poehlmann & Fiese, 2001). Evidence suggests that early dysfunctional contacts between the infant and parent due to the infant's disorganized behavioral patterns lead to poorer attachment and behavioral problems in childhood (Feldman, 2006). Conversely, early responsive and synchronous contact may positively influence cognitive and developmental outcomes for the infant (Gordon, Zagoory-Sharon, Leekman, & Feldman, 2010). Synchrony and responsiveness are essential components for young infants especially during sensitive periods. Feldman defines sensitive periods as opportunities that exist in early environments to identify essential biobehavioral experiences between parents and infants that trigger specific neurological or endocrine systems that influence gene expression, brain development, and optimal social fit (Feldman, 2015).

OT is produced primarily in the supraoptic nucleus and paraventricular nucleus of the hypothalamus (Gordon et al., 2010). Researchers originally identified OT as a female hormone because of its important roles in birth and lactation (Lee et al., 2009; Ross & Young, 2009). However, the oxytocinergic system also plays a key role in bond formation and parenting (Parker et al., 2010). In limited human studies, parental plasma OT concentrations were positively related to mother–infant affectionate contact and father–infant stimulatory contact at 6 months postpartum (Groer & Morgan, 2007; Ross & Young, 2009). OT is also involved in the control of stress, anxiety, and autonomic functions, such as heart rate, and high oxytocinergic activity is stress relieving and anxiolytic in animals and humans (Uvnas-Moberg, Arn, & Magnusson, 2005).

Cong and colleagues reported increased parental OT levels during SSC. Responses differed, however, between mothers and fathers after SSC, with the father's salivary OT levels remaining elevated after SSC ended as compared to the mother's OT levels, which dropped after the episode of SSC ended (Cong et al., 2015). We modeled the present study Cong's work but modified it to provide a more inclusive look at the mechanisms of OT and salivary cortisol (SC), a measure of stress, for mothers, fathers, and infants. We increased the episode of SSC and examined the interaction between preterm infants and their parent(s). The purpose of the present study, then, was to examine biobehavioral mechanisms associated with maternal and paternal skin-to-skin contact (M-SSC and P-SSC) with premature infants. Specifically, we examined whether changes that occur in parental (mother and/or father) salivary OT levels during SSC are associated with simultaneous changes in levels of parental anxiety and with later outcomes reflecting synchrony and responsiveness in parent–infant interactions. Although previous research has used plasma OT samples, we used more recent techniques that have been developed to reliably measure salivary OT (Carter et al., 2007; Cong et al., 2015; Feldman, Gordon, & Zagoory-Sharon, 2011). Additionally, we used SC as a measure of stress and hypothalamic–pituitary–adrenal (HPA) axis activation for parents and infants as well as a Visual Anxiety Scale (VAS) to measure parental anxiety. Our long-term goal is to work toward identifying new interventions that will increase endogenous OT release for parents and infants in the NICU to reduce stress and improve parent–infant interactions. Uncovering the biobehavioral basis of early parent–infant interactions is an important step in developing therapeutic modalities to improve health outcomes.

Method

Study Design, Setting, and Participants

We used a randomized crossover design with a 3-day study period. The mother–father–infant triads were randomly assigned to one of two study sequences using a computer program: (1) M-SSC on Day 1 and P-SSC on Day 2 or (2) P-SSC on Day 1 and M-SSC on Day 2. We recorded video of a parent–infant interaction session on Day 3, just prior to the infant's hospital discharge. We conducted the study in three NICUs: at Connecticut Children's Hartford and Farmington campuses and at Eastern Connecticut Health Network, which are all in central Connecticut.

We recruited triads via convenience sampling. Inclusion criteria included infants who were (1) 30 0/7–34 6/7 weeks' gestational age at birth and between 3 and 10 days old at the start of the study and (2) receiving either nothing per oral or on intermittent feeds to control for feeding effects on heart rate variability (Klug et al., 2000). Exclusion criteria included infants who (1) were intubated and receiving mechanical ventilation, (2) had known congenital anomalies, (3) had severe periventricular/intraventricular hemorrhage ($\geq$Grade III), (4) had undergone minor or major surgery, (5) were receiving sedation or vasopressors or analgesics to control for the effect of sedative medication on behavioral states, or (6) had positive drug exposure history to control for the effect of drugs on behavioral states and autonomic responses. Parental eligibility criteria were (1) age >18 years, (2) English speaking, and (3) without a history of depression. A maternal history of a diagnosis of depression is a significant predictor of postpartum depression and may influence OT levels (Chang, Anderson, & Wood, 1995; Parker et al., 2010). For parental history of depression, we relied on self-report during the consent process and review of infant medical records.

Based on limited data that we collected from previous triads, mean changes in salivary OT levels provided a standardized effect size (Cohen's d) of .50, an effect of precisely medium magnitude (Cong et al., 2015). Accordingly, we recruited a sample of 28 triads to provide 80% levels of power for

M-SSC and P-SSC with one-sided tests at the 5% level of statistical significance. We collected data on demographic characteristics from the infants' medical records.

Biobehavioral Measures and Instruments

We collected parent saliva samples using the unstimulated passive drool method (Grewen, Davenport, & Light, 2010). Saliva is a less intrusive method for measuring OT than plasma yet still reliable. We obtained infant saliva samples using infant swab methods (Salimetrics LLC, State College, PA). The swab, placed along the infant's cheek for 5–10 min, can collect at least 120 μl of saliva, and the minimum saliva needed for measuring OT is 70 μl. Samples from infants and parents were immediately placed in a cooler to freeze them at −20°C and then transferred to a −80°C freezer for long-term storage to await assay. We completed salivary OT assay via an enzyme immunoassay (Enzo Life Sciences, Plymouth Meeting, PA) using a method similar to that specifically developed and validated for salivary OT analysis by Carter et al. (2007). The sensitivity limit without correcting for the concentration is 15 pg/ml, and the lower limit of sensitivity is at 12.0 pg/ml with correction for the extraction. We also used an enzyme immunoassay for analysis of SC (Salimetrics LLC). The lower limit of detection is <.007 μg/dl. The intra- and interassay coefficients of variation for salivary OT and SC are 4.6% and 6%, respectively.

We measured parents' anxiety levels using a validated 8-item visual analog scale called the Visual Anxiety Scale (VAS; Cong et al., 2015; Cox, Connor, Henderson, McGuire, & Kendell, 1983). The instrument is printed on one sheet of paper and has 8 items for which the respondent marks a line to indicate the extent that each statement is true. Each item represents an emotion, for example, "I am very worried and anxious." Respondents score items using a 100-mm line with the end points *not at all* and *worse than I have ever been before*. We placed the page on a clipboard to facilitate marking a single line for each item. Parents completed the instrument just after saliva collection before, during, and after SSC. We chose this instrument due to the relative ease of use during SSC. The α reliability of the data was calculated at .93. Parents easily completed the scale, and it did not appear to interrupt the flow of holding the infant.

We measured the synchrony and responsiveness of the parent–infant interaction using the Dyadic Mutuality Code (DMC). Just prior to hospital discharge, typically when the infant was approximately 36–37 weeks' postmenstrual age, we recorded two 5-min videos of infant–adult interaction, one with each parent (Censullo, Bowler, Lester, & Brazelton, 1987). We recorded the video interaction at the infant's bedside, using privacy screens around the perimeter of the infant's bed space. A single researcher used a small portable video camera with a zoom feature and stood in the corner of the bed space to avoid standing over parents or interfering with the interaction. Parents were asked to position the infant facing them, typically on their lap, and to play with their child as they normally would without using a pacifier (Censullo, 1991). Toys were not provided or used during these interactions. All parents were provided with the same instructions. The interaction is scored using six categories: mutual attention, positive affect, turn-taking, maternal or paternal pauses, infant cues to continue or cease, and maternal or paternal sensitive responsiveness. Each category is rated 1 or 2 for a total score between 6 and 12. Previous researchers have estimated DMC reliability, construct, and concurrent validity with healthy term, preterm, and high-risk infants (Censullo et al., 1987). Two researchers independently coded all of the mother–infant and father–infant interactions. Interrater reliability was >90%. For the few videos on which the researchers' scores differed from one another, the scores were within 1 point and remained within the same category; thus, the two researchers were in complete agreement regarding scored categories. Each researcher was blinded to OT/SC results prior to watching and scoring the videos.

Study Procedures

Sampling time is an important consideration in assessing OT and SC levels for adults, who display diurnal patterns. The establishment of consistency in sampling time is thus desirable (White-Traut et al., 2009). Based on the infant's feeding schedule, the daytime interval of 1–3 p.m. was ideal for sample collection. We began sample collection during this interval 1 hr after the infant's scheduled feeding time to control for diurnal changes and feeding influences on OT and cortisol responses (Feldman, Gordon, Schneiderman, Weisman, & Zagoory-Sharon, 2010).

Pre-SSC phase (15 min). Infant saliva samples for OT/SC assays were collected during the last 10 min of this phase, then parent saliva samples were collected and the parent completed the VAS anxiety measure.

During SSC phase (60 min). The mother or father held the infant using SSC for 60 min. Depending on SSC condition (i.e., M-SSC or P-SSC), the infant was transferred to either the mother or the father from the incubator into SSC position using a standard transfer technique (Ludington-Hoe, Ferreira, Swinth, & Ceccardi, 2003). We collected the saliva samples during the last 10 min of the SSC holding, placing the swab in the infant's mouth first and then obtaining the sample from the parent. Typically, it took 5–10 min to complete the saliva collection process with parent and infant. After saliva collection was completed, the mother or father completed the VAS.

Post-SSC phase (45 min). We transferred the infant back to the incubator after the 60-min SSC session and left her or him undisturbed for 45 min. After the 45-min rest period, we collected the infant's saliva sample followed by the parent's saliva sample and then asked the parent to complete the VAS anxiety measure.

Table 1. Parental Demographic Characteristics.

Characteristic	Mother ($n = 28$)	Father ($n = 28$)
Gender, female	28 (100)	0
Race		
Asian	1 (3)	1 (3)
Black	3 (11)	4 (14)
Hispanic	5 (18)	4 (14)
White	19 (68)	19 (68)
Age (years), mean ± *SD*	32 ± 1.13	33 ± 1.38
20–24	4 (14)	3 (11)
25–29	6 (22)	9 (32)
30–34	8 (29)	4 (14)
35–39	8 (29)	7 (25)
40–44	1 (3)	3 (11)
45–52	1 (3)	2 (7)
Employment status		
Employed full-time	19 (69)	24 (88)
Employed part-time	4 (14)	1 (3)
Full-time homemaker	2 (7)	1 (3)
Student	1 (3)	1 (3)
Unemployed	2 (7)	1 (3)
Education level		
Completed high school	2 (7)	3 (11)
Completed some college (1–3 years)	9 (32)	12 (43)
Completed 4 years of college	8 (29)	10 (35)
Completed graduate school	9 (32)	3 (11)
Marital status		
Married	23 (82)	23 (82)
Single	5 (18)	5 (18)

Note. Data are *n* (%), unless otherwise indicated.

Table 2. Infant Demographic Characteristics.

Characteristics	*N* (%) or Mean ± *SD*
Gender, female	9 (32)
Race	
Asian	2 (7)
Black	4 (14)
Hispanic	5 (18)
White	17 (61)
Gestational age at birth (weeks), mean ± *SD*	33 ± 1.57
30–30 6/7	4 (14)
31–31 6/7	5 (18)
32–32 6/7	1 (3)
33–33 6/7	3 (11)
34–34 6/7	15 (54)
Birth weight (g), mean ± *SD*	1,882 ± 416.66
900–1,300	3 (7)
1,301–1,700	5 (18)
1,701–2,100	12 (43)
2,101–2,500	5 (18)
2,501–2,900	3 (3)
SNAPPE II score, mean ± *SD*	3.93 ± 7.78
0	21 (75)
7–10	3 (11)
18–21	3 (11)
22–27	1 (3)
Apgar score (1 min), mean ± *SD*	
0–4	4 (14)
5–7	7 (25)
8–10	17 (61)
Apgar score (5 min), mean ± *SD*	8.29 ± 1.27
0–4	1 (3)
5–7	4 (14)
8–10	23 (82)
Mode of delivery	
Vaginal	11 (39)
Cesarean	17 (61)

Note. Data are *n* (%) unless otherwise indicated. SNAPPE II = Score for Neonatal Acute Physiology with Perinatal Extension.

Data Analysis

We analyzed data using IBM SPSS Version 22. To describe demographic characteristic variables, we used descriptive statistics. We used repeated-measures analysis of variance (RM-ANOVA) to describe within-subject salivary OT and SC differences across time points (i.e., before, during, and after SSC) as a repeated factor in a one-tailed test with 5% of statistical significance. Normality of data was accounted for in differences in salivary OT and SC measures, so we used parametric testing. We used the same method for analysis of parental VAS measures and standardized the effect of SSC over time, with participants serving as their own controls. Because we applied Bonferroni correction for all three analyses, we identified significance at $p \leq .01$ to attend to outliers at the individual level. We used paired *t* tests to examine mother, father, and infant salivary OT levels and the DMCs of the mother–infant and father–infant interactions.

Results

We screened 112 infant medical charts for study participation and determined that 54 triads did not meet eligibility criteria. We approached 58 parents for recruitment, 26 of whom declined participation. Of the 32 triads we approached for study participation, 4 were discharged prior to data collection, leaving 28 triads who participated and provided data for analysis. Table 1 describes the parental demographic characteristics, while Table 2 depicts the infants' demographic characteristics. We randomized 15 triads to sequence one (M-SSC on Day 1, P-SSC on Day 2) and 13 to sequence two (P-SSC on Day 1, M-SSC on Day 2). The majority of parents were White (68%) and college educated (93% of mothers and 89% of fathers). The mothers' mean age was 32 years, while the fathers' was 33. The infants were relatively healthy, with a mean Score for Neonatal Acute Physiology with Perinatal Extension score of 3.93. This score is a valid indicator of an infant's severity-of-illness predictor of mortality risk. Infants were born at a mean of 33 weeks' postmenstrual age. The majority of infants were White (61%) males (68%). Most mothers (89%) had held their infants SSC prior to the study, while only some of the fathers (27%) had. Only a small percentage of parents (32% of mothers, 21% of fathers) had previous SSC experience with another infant. We identified no significant relationship between OT level and previous SSC holding experiences.

Table 3. Mother, Father, and Infant Salivary Oxytocin and Cortisol Levels and Mother and Father Anxiety Levels in Response to Skin-to-Skin Contact.

Variable	Before SSC *M* ± *SD*	During SSC *M* ± *SD*	After SSC *M* ± *SD*	*F*	p^a	η^{2b}
Oxytocin (pg/ml)						
Mother (*n* = 28)	161.97 ± 104.91	275.09 ± 173.54	202.25 ± 104.91	23.19	.001	.094
Infant M-SSC (*n* = 28)	134.71 ± 104.69	306.72 ± 275.48	223.44 ± 214.02	8.05	.002	.052
Father (*n* = 27)[c]	142.99 ± 112.69	211.86 ± 159.87	153.85 ± 88.32	21.88	.001	.066
Infant P-SSC (*n* = 27)	130.71 ± 143.67	346.87 ± 291.63	260.98 ± 232.08	8.21	.001	.137
Cortisol (μg/dl)						
Mother (*n* = 28)	.152 ± .140	.147 ± .138	.109 ± .085	1.94	.153	.011
Infant M-SSC (*n* = 28)	.090 ± .132	.024 ± .033	.055 ± .071	5.85	.005	.063
Father (*n* = 27)	.167 ± .223	.111 ± .111	.097 ± .093	2.81	.070	.020
Infant P-SSC (*n* = 27)	.081 ± .064	.019 ± .024	.051 ± .058	11.48	.001	.011
Anxiety levels						
Mother (*n* = 28)	72.00 ± 77.84	28.54 ± 54.72	32.14 ± 61.06	9.69	.001	.060
Father (n = 27)	43.59 ± 58.10	15.57 ± 19.57	24.41 ± 36.08	8.86	.003	.053

Note. Data were calculated using repeated-measures analysis of variance. Salivary oxytocin was measured in pg/ml and salivary cortisol was measured in μg/dl. M-SCC = maternal skin-to-skin contact condition; P-SCC = paternal skin-to-skin contact condition; VAS = Visual Analog Scale measurement of parental stress and anxiety; SSC = skin-to-skin contact.
[a]Use of the Bonferroni adjustment required significance at the $p < .01$ level. [b]Guidelines indicate .02 = *small effect*; .13 = *medium effect*; .26 = *large effect*.
[c]One father did not complete all data collection procedures.

Salivary OT Levels

Table 3 describes mother, father, and infant salivary OT and SC levels for the pre-, during-, and post-SSC phases. Figure 1 depicts mean salivary OT levels for mothers, fathers, and infants at each time point. Maternal salivary OT levels significantly increased from pre-SSC (*M* = 161.97, *SD* = 104.91 pg/ml) to during SSC (*M* = 275.09, *SD* = 173.54 pg/ml) and then dropped post-SSC (*M* = 202.25, *SD* = ±104.91 pg/ml). We observed a similar response with the infant salivary OT levels during the M-SSC condition, with a significant increase from pre-SSC (*M* = 134.71, *SD* = 104.69 pg/ml) to during SSC (*M* = 306.72, *SD* = 275.48) and then a decrease to post-SSC (*M* = 223.44, *SD* = 214.02 pg/ml). RM-ANOVAs showed that salivary OT levels were significantly higher during SSC for mothers, $F(1, 27) = 23.19$, $p < .001$, and infants, $F(2, 54) = 8.05$, $p < .002$, as compared to before and after SSC.

In the P-SSC condition, paternal OT levels increased from pre-SSC (*M* = 142.99, *SD* = 112.69 pg/ml) to during SSC (*M* = 211.86, *SD* = 159.87 pg/ml) and then dropped post-SSC (*M* = 153.85, *SD* = 88.32 pg/ml). Likewise, the infants' OT levels during this condition significantly increased from pre-SSC (*M* = 130.71, *SD* = 143.67 pg/ml) to during SSC (*M* = 346.87, *SD* = 291.63) and decreased post-SSC (*M* = 260.98, *SD* = 232.08 pg/ml). RM-ANOVAs showed that salivary OT levels were significantly higher during P-SSC for fathers, $F(2, 52) = 8.21$, $p < .001$, and infants, $F(2, 52) = 21.88$, $p < .001$, as compared to before and after SSC. There were no differences in infant OT levels between the two conditions at each time point.

Salivary Cortisol Levels

Table 3 and Figure 2 depict maternal, paternal, and infant cortisol levels at each time point. Infant SC levels decreased during the M-SSC condition from pre-SSC (*M* = .09, *SD* = 132 μg/dl) to during (*M* = .024, *SD* = 033 μg/dl) and then increased again post-SSC (*M* = .055, *SD* = 071 μg/dl). Using RM-ANOVA, we found that infant SC levels were significantly lower, $F(1, 26) = 5.85$, $p < .001$, during M-SSC as compared to pre- and post-SSC.

Infants had similar responses during the P-SSC condition, with their SC decreasing from pre-SSC (*M* = .81, *SD* = .064 μg/dl) to during SSC (*M* = .019, *SD* = .024 μg/dl) and then increasing slightly post-SSC (*M* = .051, *SD* = .058 μg/dl). RM-ANOVA showed that infant SC levels were significantly lower in the P-SSC condition during SSC, $F(2, 52) = 11.48$, $p < .001$, compared to pre- and post-SSC. Although SC levels decreased for both mothers and fathers during SSC, none of the changes were statistically significant.

Parental Anxiety Levels

Table 3 and Figure 3 display maternal and paternal anxiety scores pre-, during-, and post-SSC. Maternal anxiety levels dropped from pre-SSC (*M* = 72.00, *SD* = 77.84) to during SSC (*M* = 28.54, *SD* = 54.72) and post-SCC (*M* = 32.14, *SD* = 61.06). Paternal anxiety levels also decreased from pre-SSC (*M* = 43.59, *SD* = 58.10) to during SSC (*M* = 15.57, *SD* = 19.57) and then increased slightly post-SSC (*M* = 24.41, *SD* = 36.08). Using RM-ANOVA, we found that maternal anxiety scores were significantly lower during SSC, $F(1, 26) = 9.69$, $p < .001$, compared to pre- and post-SSC. Paternal anxiety levels were also significantly lower during SCC, $F(1, 26) = 8.86$, $p < .003$, compared to pre- and post-SSC. There were no significant correlations between maternal and paternal anxiety levels and their respective salivary OT or SC levels.

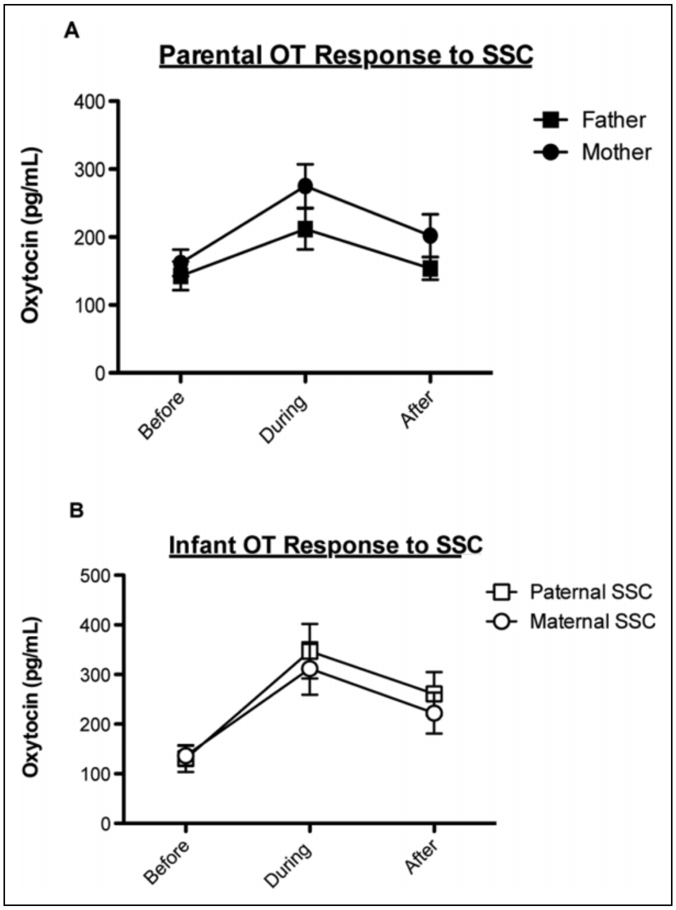

Figure 1. Salivary oxytocin (OT) responses to skin-to-skin contact (SSC; mean and standard error of the mean [SEM].

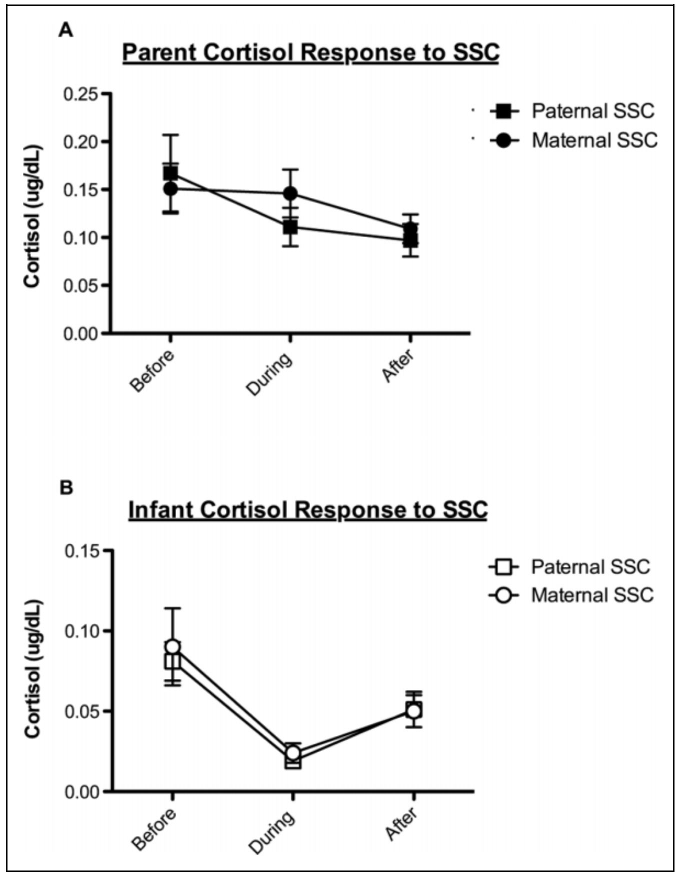

Figure 2. Salivary cortisol (SC) responses to skin-to-skin contact (SSC; mean and standard error of the mean [SEM]).

Parent–Infant Interaction

We grouped the parent–infant interactions into three categories based on the video scoring: We considered scores between 6 and 8 to indicate low responsiveness, a score of 9 moderate responsiveness, and a score of 10–12 high responsiveness, or a synchronous interaction. All of the mothers (n = 28) and 26 fathers completed the videotaped interactions. The majority of mothers 67% (n = 19) scored as moderately responsive, with only 7% (n = 2) scoring in the low responsive group and 26% (n = 7) scoring as highly responsive. The fathers also scored as predominately moderately responsive (58%, or n = 15), with 16% (n = 4) scoring in the low responsiveness group and 26% (n = 7) scoring as highly responsive. Parents and infants with higher OT levels during SSC had significantly more synchronicity and responsiveness in their interactions. Paternal (r = .49, $p < .01$) and maternal (r = .53, $p < .005$) OT levels were moderately yet significantly correlated with the father–infant and mother–infant scores on the videotaped interactions, respectively. We identified no significant correlations between maternal or paternal SC levels and scores on the videotaped parent–infant interactions.

Correlations Among Parental Biomarkers

There was a significant negative correlation ($r = -.60$, $p < .001$) between paternal OT and SC levels, but maternal OT and SC levels were not correlated. Maternal OT and paternal OT levels were moderately yet significantly correlated (r = .45, $p < .02$), using Spearman's correlation. This finding indicates mothers with higher OT levels were more likely to be paired with fathers with higher OT levels.

Discussion

In the present study, we found that 60 min of SSC significantly increased salivary OT levels for mothers, fathers, and premature infants; decreased SC levels for premature infants; and decreased anxiety levels for mothers and fathers. We also found that parental OT levels were significantly and moderately correlated with the level of responsiveness and synchronism exhibited in videotaped parent–infant interaction sessions. These results are consistent with Cong's previous finding indicating that SSC activates OT release in mothers and fathers (Cong et al., 2015). In the present study, however, salivary OT levels dropped significantly for both mothers and fathers after SSC, whereas Cong et al. reported that maternal levels decreased but paternal levels remained elevated after SSC. This

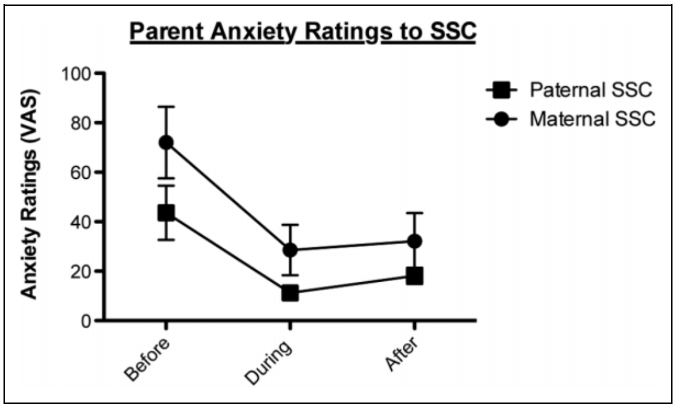

Figure 3. Parental anxiety levels in response to skin-to-skin contact (SSC; mean and standard error of the mean [SEM]). Anxiety was measured using the Visual Anxiety Scale (VAS).

difference may be related to the extended timing of the during- and post-SSC phases in the present study. Cong et al. reported the salivary OT responses for 26 mothers and 19 fathers at three time points: pre-SSC, during 30 min of SSC, and 30 min after SSC. In the current study, we extended the length of SSC to 60 min and collected post-SSC saliva at 45 min after SSC. Thus, the stages of OT release that we measured may have differed from those that Cong et al. measured because of the differences in time points.

Research suggests that SSC may be used to support developing relationships between premature infants and their parents (Feldman, 2013; Ferber & Makhoul, 2004). Findings of the present study indicate that salivary OT levels increased for both infants and parents during a session of SSC and that infant–parent dyads with higher OT levels had more responsive and synchronous interactions. During sensitive periods of bond formation between the parent and preterm infant, the infant's brain is sensitized to reciprocal occurrences in physiological systems, such as brain stem–mediated homeostasis responses, as well as patterns of behavior during parent–infant interactions (Feldman, 2015; Feldman, Rosenthal, & Eidelman, 2014; Feldman, Gordon, Influs, Gutbir, & Ebstein, 2013). The literature defines these sensitive periods in early infancy as critical for supporting the developing relationships between infants and their parents (Feldman, 2013, 2015). Additionally, early responsive and synchronous contact between parent and infant may positively influence cognitive and developmental outcomes for the child (Gordon et al., 2010).

Conversely, our results indicate that mothers with lower salivary OT levels had less synchronous and less responsive interactions with their premature infants. In a recently published study that examined biobehavioral factors in child health outcomes, researchers found that maternal stress and maternal–child engagement play significant roles in the regulation of the infant's stress responses (Clowtis, Kang, Padhye, Rozmus, & Barratt, 2016). These researchers found that mothers with lower levels of maternal–child engagement had elevated SC levels and lower OT levels.

Animal studies have revealed that biobehavioral mechanisms embedded within the mother–infant dyad help to organize the infant's physiological systems, stress response, and social orientation (Champagne, Diorio, Sharma, & Meaney, 2001; Hofer, 1994). Feldman (2013) describes the sensitive period of parent–infant interactions as the opportunity for bond formation, where the infant's brain is sensitized to mutual influences, physiologically and behaviorally, to create a synchronous process. In the present study, SSC increased endogenous OT release for parents and infants and facilitated synchronous interactions. Infant SC levels, a measure of the stress response, also decreased during SSC irrespective of whether the infant was being held by the mother or the father.

These results have implications for the clinical setting, where SSC could be used as an intervention to decrease anxiety in mothers and fathers and the stress response in premature infants in the NICU. Only a few studies previous have reported on fathers and SSC (Cong et al., 2015; Gloppestad, 1998; Poehlmann & Fiese, 2001). We included fathers in our study in an effort to both examine the OT mechanism associated with SSC and engage fathers in the practice of SSC. This study supports the need to encourage fathers to participate in SSC as well as mothers.

Prior research has shown that maternal responses that are adaptive and sensitive to the infant's behavioral repertoire support the infant's use of regulatory strategies to enhance calm, alert states, and facilitate learning (Kalinauskiene et al., 2009). Our findings in the present study of a biobehavioral response of a decrease in SC during SSC and improvement in infant coregulatory are consistent with those of previous studies (Neu & Robinson, 2010). Premature infants are at increased risk of less synchronous interactions due to their developing nervous system and diffuse behavioral cues (Forcada-Guex, Pierrehumbert, Borghini, Moessinger, & Muller-Nix, 2006). The present study confirms that SSC may be used to support these developing relationships by facilitating more synchronous interactions between parents and their premature infant.

Implications for Practice

In the present study, the infants' oxytocinergic system was activated whether the mother or the father was practicing SSC. Engaging fathers in SSC with their premature infants is therefore a priority in order to enhance their developing relationships. Additional research is needed to understand the roles salivary OT plays in the interactions between fathers and preterm infants.

More generally, the present study supports the practice of using SSC to decrease the infant stress responses and parental anxiety in the NICU and enhance the developing parent–infant relationships. SSC activated endogenous OT release for mothers, fathers, and infants and decreased SC levels in infants. These findings are consistent with the notion that early infancy is a sensitive period in the development of HPA axis regulation and have significant implications for the use of SSC as an intervention to improve child health outcomes via biobehavioral mechanisms that facilitate synchronous interactions between parents and their premature infants.

Limitations

Despite the small sample size, the present study had statistically significant results with robust effects showing that SSC activates OT release in mothers, fathers, and premature infants, in addition to decreasing infant SC levels and parental anxiety. Research with a larger sample size is needed, however, to generalize these findings. Our sample was primarily Caucasian with college-educated parents, which may have influenced the findings. Another limitation was the crossover study design, which does not allow for a clear definition of causality. Our convenience sampling techniques may have influenced the findings as well: Although SSC was a standard of practice in all recruiting NICUs, parents may have declined to participate because they did not want to practice SSC with their infants.

Conclusion

The present study addresses a gap in the body of knowledge regarding the mechanisms that link parent–infant contact to biobehavioral responses. Skin-to-skin holding activates OT release for mothers, fathers, and infants and decreases infant SC levels and parental anxiety. The nursing intervention of facilitating the implementation of SSC thus may be used to reduce parent and infant stress in the NICU. This study is also an important step in exploring the use of OT as a potential moderator to improve infant developmental outcomes and the responsiveness of the interactions between mothers and infants and fathers and infants.

Author Contributions

Dorothy Vittner contributed to conception, design, acquisition, analysis, and interpretation; critically drafted the manuscript; revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy. Jacqueline McGrath and JoAnn Robinson contributed to conception, acquisition, analysis, and interpretation; critically revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy. Gretchen Lawhon and Regina Cusson contributed to conception, acquisition, analysis, and interpretation; critically revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy. Leonard Eisenfeld contributed to design, acquisition, analysis, and interpretation; critically revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy. Stephen Walsh and Erin Young contributed to acquisition, analysis, and interpretation; critically revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy. Xiaomei Cong contributed to design, critically revised the manuscript, gave final approval, and agrees to be accountable for all aspects of work ensuring integrity and accuracy.

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