Original Article

Skin-to-Skin Contact Improves Gas Exchange in Premature Infants

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OBJECTIVE:
Skin-to-skin contact (kangarooing) is regarded as an important method to improve intensive care in premature infants. There is still demand for investigations of its impact on physiological parameters.

STUDY DESIGN:
We examined 53 preterm infants of <1800 gm in a prospective, pretest-test-posttest design study during incubator care (60 minutes), skin-to-skin contact (90 minutes), and incubator care again (90 minutes). Heart rate, respiratory rate, oxygen saturation (SaO_2), transcutaneous pO_2 ($tcpO_2$), transcutaneous pCO_2, rectal temperature, and fraction of inspired oxygen were measured.

RESULTS:
The heart rate increased during skin-to-skin contact by 5 beats per minute ($p < 0.001$), the respiratory rate dropped by 5/minute ($p < 0.01$), the SaO_2 improved by 0.4% ($p < 0.05$) accompanied by an increase of $tcpO_2$ of 4.8 mm Hg ($p < 0.001$), the $tcpCO_2$ dropped by 1.2 mm Hg ($p < 0.001$), and the rectal temperature increased by 0.3 ° C ($p < 0.001$). Analyzing three groups separately by postnatal weight, we observed the smallest increase in heart rate and the highest decrease in respiratory rate in infants of <1000 gm ($p < 0.001$). The increase in SaO_2 and in the $tcpO_2$ doubles in infants of <1000 gm compared with infants of >1000 gm ($p < 0.001$). All changes were independent of postnatal age.

CONCLUSION:
During skin-to-skin contact, preterm infants not only remain clinically stable but also show a more efficient gas exchange. Although the patient is removed (transferred) from the incubator, there is no risk of hypothermia even in infants of <1000 gm.

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Skin-to-skin contact is now a widely used and approved method to interrupt the long-time separation of premature infants and their parents due to incubator care during intensive care.[1–3] During skin-to-skin contact, the mother holds her diaper-clad premature infant against her skin, covering him or her with her clothing or a towel. Although positive effects of early skin-to-skin contact on the psychological state of the mother, mother-infant-bonding, lactation, and stimulation of the infant have been proven and recognized,[4–10] several studies failed to show significant benefits with regard to physiological measurements.[11–13] Other studies report increases in heart rate[14,15] and transcutaneous oxygen pressure,[15] as well as more regular breathing.[6] Reports about temperature stability are contradictory.[11,14]

This study includes 53 premature infants of <1800 gm, which is a large number of patients compared with other studies, and examines the effects of skin-to-skin contact compared with incubator care. Heart rate, respiration rate, oxygen saturation, pO_2, pCO_2, body temperature, and inspired oxygen concentration were measured. Furthermore, the influence of body weight and postnatal age was analyzed to determine which infants benefit the most from skin-to-skin contact.

METHODS

Patients

A total of 53 preterm infants (22 girls and 31 boys) were studied. The mean birth weight was 1247 gm (range 550 gm to 1830 gm) and the mean gestational age was 30 weeks (range 25 to 35 weeks). The median postnatal age was 10 days (range 1 to 68 days) and the mean postnatal weight was 1253 gm (range 631 gm to 1700 gm). Five ventilated infants were included. Exclusion criteria were as follows: (1) Postnatal weight of >1800 gm; (2) septicemia; (3) life-threatening, unstable general condition (rectal temperature of <36 ° C, SaO_2 of < 80%); (4) intracranial hemorrhage (grade IV); and (5) severe congenital anomalies.

Cardiorespiratory Variables and Temperature Measurements

Heart rate, respiratory rate, SaO_2, transcutaneous pO_2 ($tcpO_2$), transcutaneous pCO_2 ($tcpCO_2$), and rectal temperature were continuously measured and automatically registered every 5 minutes during the study (Kontron Kolormon 7250; Kontron Instruments) (heart rate and respiratory rate accuracy ± 1%, SaO_2 accuracy ± 2%, $tcpO_2$ and $tcpCO_2$ accuracy ± 1mm Hg, and temperature accuracy ± 0.1 ° C).

Inspired Oxygen Concentration

Oxygen was delivered by an oxygen mask or, in the case of the ventilated patients, with a ventilator (Babylog 8000; Dräger). The oxygen

Table 1 Differences Between the Measured Parameters in 53 Preterm Infants

Parameter	Before skin-to-skin contact	During skin-to-skin contact	After skin-to-skin contact	Multivariate test statistic (Wilks)
Heart rate (minute)	144.0 ± 14.0	149.0 ± 16.0	145.0 ± 16.0	$p < 0.001$
Respiratory rate (minute)	58.0 ± 13.0	53.0 ± 12.0	56.0 ± 12.0	$p < 0.010$
SaO_2 (%)	92.6 ± 3.2	93.0 ± 3.1	92.3 ± 3.0	$p < 0.050$
$tcpO_2$ (mm Hg)	57.4 ± 13.1	62.2 ± 15.0	57.8 ± 15.3	$p < 0.001$
$tcpCO_2$ (mm Hg)	41.9 ± 7.3	40.7 ± 7.1	40.7 ± 7.1	$p < 0.001$
Temperature (°C)	37.0 ± 0.3	37.3 ± 0.3	37.2 ± 0.2	$p < 0.001$
FiO_2 (%)	24.3 ± 7.9	23.8 ± 7.2	24.1 ± 8.4	

concentration was continuously measured and registered every 5 minutes (Oxydig and Babylog 8000; Dräger).

Study Protocol

A prospective pretest-test-posttest design was used with infants serving as their own control, as used in other studies.[12–14] Registration of the infants was performed under three conditions: 1 hour in the incubator, 1.5 hours of skin-to-skin contact, and 1.5 hours in the incubator again. In total, 12 values of every variable under each condition were registered. The first 30 minutes after the transfers were excluded from analysis to minimize the effects of changes due to the adaptation process.

The measurements were randomly performed during the morning and afternoon between the 4-hour nursing routine. The infant was naked except for a diaper and was placed in a prone horizontal position in the incubator at a thermoneutral temperature (30 ° C to 36 ° C, depending on weight, gestational, and postnatal age). After 1 hour of measurements, the infant was transferred to the mother, who was reclining in a comfortable chair. The infant was on the mother's chest in a prone position at a tilt of ~60° and was covered with a towel; the head was left uncovered (mean room temperature 28 ° C, mean relative humidity 54%). Measurements continued for 1.5 hours. After the skin-to-skin contact, the infant was transferred back into the incubator, placed again in a prone horizontal position, and measurements were recorded for an additional 1.5 hours.

Statistical Analysis

The data were analyzed with SPSS 7.5 for Windows (SPSS Inc., Chicago, IL). Mean values of every physiological variable for the three study periods were compared by the multivariate test statistic of Wilks as a parametric test for repeated measurements. A p value of <0.05 was considered statistically significant.

RESULTS

Cardiorespiratory Variables and Temperature Measurements

The heart rate increased and the respiratory rate dropped significantly during skin-to-skin contact ($p < 0.01$); after skin-to-skin contact, values were comparable with those seen for the time initially spent in the incubator (Table 1). Whereas the SaO_2 showed a very mild but significant increase ($p < 0.05$), the $tcpO_2$ increased considerably ($p < 0.001$) and the $tcpCO_2$ decreased ($p < 0.001$) during skin-to-skin contact (Table 1). After the skin-to-skin contact, the values of SaO_2 and $tcpO_2$ decreased again, whereas $tcpCO_2$ stayed at the same lower level as during skin-to-skin contact. The rectal temperature also increased significantly ($p < 0.001$) during skin-to-skin contact and stayed even after skin-to-skin contact at a higher level than before (Table 1).

Inspired Oxygen Concentration

There was no change in the fraction of inspired oxygen (FiO_2) during skin-to-skin contact (Table 1). Of the 53 patients, only 21 infants had an increased FiO_2. In these infants, the mean FiO_2 decreased by 2.1%. Because of the small number of patients in this group, no statistical calculation of significance was done. In five patients with a mean FiO_2 of 40%, a considerable decrease of 7% was observed. Four of the five infants were doing skin-to-skin contact for the first time.

Effects of Body Weight

An analysis of three groups separated by postnatal weight (<1000 gm (9 infants), 1000 gm to 1500 gm (29 infants), >1500 gm (15 infants)) showed the smallest heart rate increase and the highest respiratory rate decrease during skin-to-skin contact in the infants weighing <1000 gm ($p < 0.001$) (Table 2). The increase in SaO_2 ($p < 0.01$) and $tcpO_2$ ($p < 0.001$) during skin-to-skin contact is twice as high in the infants weighing <1000 gm compared with the infants

Table 2 Differences Between the Measured Parameters in 53 Preterm Infants According to the Postnatal Weight

Parameter	Postnatal weight	Before skin-to-skin contact	During skin-to-skin contact	After skin-to-skin contact	Multivariate test statistic (Wilks)
Heart rate (1/minute)	<1000 g	140.0 ± 21.0	141.0 ± 22.0	142.0 ± 20.0	$p < 0.001$
	1000–1500 g	146.0 ± 13.0	150.0 ± 16.0	146.0 ± 16.0	
	>1500 g	144.0 ± 9.0	151.0 ± 10.0	147.0 ± 11.0	
Respiratory rate (1/minute)	<1000 g	59.0 ± 12.0	50.0 ± 11.0	57.0 ± 8.0	$p < 0.001$
	1000–1500 g	60.0 ± 12.0	55.0 ± 13.0	57.0 ± 14.0	
	>1500 g	52.0 ± 14.0	51.0 ± 11.0	54.0 ± 12.0	
SaO_2 (%)	<1000 g	93.3 ± 2.6	94.2 ± 2.9	92.6 ± 2.7	$p < 0.010$
	1000–1500 g	92.1 ± 3.1	92.3 ± 3.1	91.7 ± 2.9	
	>1500 g	93.1 ± 3.6	93.7 ± 3.0	93.4 ± 3.3	
$tcpO_2$ (mm Hg)	<1000 g	60.4 ± 15.2	67.9 ± 16.7	61.3 ± 19.6	$p < 0.001$
	1000–1500 g	56.2 ± 12.5	60.0 ± 14.5	56.5 ± 14.3	
	>1500 g	57.9 ± 13.6	62.9 ± 15.0	58.1 ± 15.0	
$tcpCO_2$ (mm Hg)	<1000 g	43.7 ± 5.9	42.9 ± 6.5	43.5 ± 6.7	$p < 0.010$
	1000–1500 g	42.9 ± 7.2	41.3 ± 6.6	41.4 ± 6.6	
	>1500 g	39.0 ± 7.8	38.2 ± 8.2	38.1 ± 7.8	
Temperature (°C)	<1000 g	37.0 ± 0.4	37.1 ± 0.4	37.1 ± 0.3	$p < 0.001$
	1000–1500 g	36.9 ± 0.4	37.3 ± 0.3	37.2 ± 0.2	
	>1500 g	37.1 ± 0.3	37.4 ± 0.2	37.2 ± 0.2	
FiO_2 (%)	<1000 g	24.0 ± 6.5	22.8 ± 4.6	23.3 ± 4.5	
	1000–1500 g	25.6 ± 9.8	25.1 ± 9.1	25.6 ± 10.8	
	>1500 g	21.8 ± 2.4	21.6 ± 2.0	21.7 ± 2.7	

weighing >1000 gm, whereas the drop in $tcpCO_2$ ($p < 0.01$) is more important in the group of the infants between 1000 to 1500 gm (Table 2). The increase in the rectal temperature during skin-to-skin contact is smaller in the infants weighing <1000 gm than in the infants weighing >1000 gm ($p < 0.001$; Table 2). The FiO_2 decreased during skin-to-skin contact to a greater extent in the infants weighing <1000 gm compared with the infants weighing >1000 gm (Table 2). The decrease is not statistically significant. The mean values of all of the parameters did not differ significantly between the groups.

Effects of Postnatal Age

Analyzing two groups by postnatal age (<10 days (28 infants), >10 days (25 infants)) showed that the increase in the heart rate ($p < 0.001$) and the decrease in the respiratory rate ($p < 0.01$) during skin-to-skin contact hardly differ between both groups (Table 3). The increase in SaO_2 ($p < 0.05$) is the same in both groups, but in the infants that were <10 days of age, the SaO_2 after skin-to-skin contact falls to below the value before skin-to-skin contact (Table 3). The increase in $tcpO_2$ ($p < 0.001$) during skin-to-skin contact is comparable in both groups. The decrease in $tcpO_2$ after skin-to-skin contact is greater in the infants of <10 days of age (Table 3). The $tcpCO_2$ decreased similarly in both groups ($p < 0.001$). The increase in the rectal temperature is identical ($p < 0.001$; Table 3). The FiO_2 decreased in both groups, but this did not reach statistical significance (Table 3). The mean value of heart and respiratory rate, SaO_2, $tcpO_2$, rectal temperature, and FiO_2 differed significantly between both groups: heart and respiratory rate, $tcpCO_2$, rectal temperature, and FiO_2 were higher; SaO_2 and $tcpO_2$ were lower in the infants that were >10 days old.

DISCUSSION

Our study demonstrates the safety and efficacy of skin-to-skin contact in preterm infants. All values of the physiological parameters remained within normal limits before, during, and after skin-to-skin contact. Heart rate increased and respiratory rate decreased during skin-to-skin contact. Smaller infants showed a lower increase in heart rate and a higher decrease in respiratory rate. Postnatal age had no

Table 3 Differences between the measured parameters in 53 preterm infants according to the postnatal age

Parameter	Postnatal age	Before skin-to-skin contact	During skin-to-skin contact	After skin-to-skin contact	Multivariate test statistic (Wilks)
Heart rate (1/minute)	<10 days	138.0 ± 10.0	142.0 ± 12.0	139.0 ± 11.0	$p < 0.001$
	>10 days	152.0 ± 14.0	156.0 ± 17.0	153.0 ± 16.0	
Respiratory rate (1/minute)	<10 days	54.0 ± 12.0	49.0 ± 10.0	53.0 ± 13.0	$p < 0.010$
	>10 days	62.0 ± 13.0	57.0 ± 13.0	59.0 ± 12.0	
SaO_2 (%)	<10 days	93.9 ± 3.0	94.3 ± 2.7	93.3 ± 2.8	$p < 0.050$
	>10 days	91.2 ± 2.8	91.6 ± 3.0	91.2 ± 2.9	
$tcpO_2$ (mm Hg)	<10 days	63.2 ± 9.9	68.1 ± 12.3	61.9 ± 14.5	$p < 0.010$
	>10 days	50.0 ± 13.4	55.6 ± 15.3	53.1 ± 1.50	
$tcpCO_2$ (mm Hg)	<10 days	40.0 ± 6.4	39.0 ± 6.3	39.2 ± 6.8	$p < 0.001$
	>10 days	44.1 ± 7.7	42.5 ± 7.6	42.3 ± 7.2	
Temperature (° C)	<10 days	36.9 ± 0.4	37.2 ± 0.3	37.1 ± 0.2	$p < 0.001$
	>10 days	37.1 ± 0.3	37.4 ± 0.3	37.3 ± 0.2	
FiO_2 (%)	<10 days	22.1 ± 4.2	21.6 ± 2.7	21.8 ± 3.1	
	>10 days	26.7 ± 10.2	26.2 ± 9.6	26.7 ± 11.4	

measurable influence on changes in heart or respiratory rate. We observed an increase in SaO_2 and pO_2 during skin-to-skin contact, whereas pCO_2 decreased. In infants weighing <1000 gm, the increase in SaO_2 and pO_2 was twice as high as that seen for the infants weighing >1000 gm. The decrease in pCO_2 in infants weighing <1000 gm is lower than that seen for the infants weighing between 1000 and 1500 gm. Postnatal age had hardly any influence on these parameters.

Other studies[1,13–15] also found an increase in the heart rate during skin-to-skin contact. Increase in heart rate with head up-tilting, as during the positioning of the infants on their mothers' chest, is assumed to be due to gravity causing pooling of blood and thereby activating baroreceptors.[16,17] In addition, the heart rate increase may be an indirect effect of the rise in body temperature.[14] Other results demonstrated an increase in heart rate in response to skin-to-skin massaging and rocking.[18,19] This could be understood as activation of the central nervous system (within an acceptable range) as well as a psychophysiological response to the mother's presence.[1,20]

A possible explanation for the decreased respiratory rate and pCO_2, as well as the increased pO_2, is also based on the upright position of the infant. This was partly observed in other studies as well.[13,15] Ventilation and perfusion are gravity-dependent,[21] so an upright position might lower the respiration rate and at the same time raise the pO_2. Stark et al.[22] described an increase in tidal volume and the rib-cage moving more synchronously when newborns were tilted upright. Upright posture could also allow an increase in FRC by taking the weight of abdominal contents off the diaphragm.[23] Both could result in a decreased respiratory rate, increased pO_2, and decreased pCO_2. Infants sleep more quietly during skin-to-skin contact, which might also result in a more tranquil respiration.[11,15,24] Moreover, it is known that the sleep state may result in a higher pO_2 during quiet sleep.[25]

The increase in SaO_2 of only 0.4% is due to its position at the top end of the oxygen-hemoglobin dissociation curve. In this range, a substantial rise in pO_2 cannot be accompanied by a large rise in hemoglobin SaO_2.

Influence of weight or age on these processes has not been examined so far, and our findings should encourage further investigation. In our study, the positive changes of all parameters were clearly higher in the infants of <1000 gm, especially regarding respiratory rate, SaO_2, and $tcpO_2$. It is unclear what might cause a higher responsiveness of the smaller infants. At the same time, infants that were <10 days of age showed the same changes as infants that were >10 days old. No negative effects by age could be observed, but it should be noted that the physiological parameters differed significantly between the two analyzed groups.

Wieland et al.[13] showed similar changes in heart rate, respiration rate, and pO_2 during skin-to-skin contact, although none of these changes was statistically significant. This might be due to the smaller amount of patients (39 vs 53 in our study).

The increase in body temperature was also examined by Bauer et al.[26–28] They found that a temperature increase during skin-to-skin contact was not combined with an increase in oxygen (equaling energy) consumption in preterm infants.

There was a trend for the FiO_2 to decrease, especially in infants weighing <1000 gm. This did not reach statistical significance, as it differed highly between the infants. Opposite to this, Wieland et al.[13] described a considerable increase in oxygen concentration during skin-to-skin contact, which was also not significant. This study had a duration of skin-to-skin contact of 60 minutes, which was 30 minutes shorter than ours. The transfer from incubator to their mothers' chest is especially difficult for the oxygen-dependent infants. The longer adaptation period in our study might have positively influenced the FiO_2. Wieland et al.[13] used oxygen masks only during skin-to-skin contact; before and after skin-to-skin contact, oxygen was provided over the incubator. This makes a comparison difficult. The possible mechanisms for reduced respiratory rate and pO_2 might also explain a decreased inspired oxygen concentration during skin-to-skin contact. Further studies with a higher number of oxygen-dependent infants are necessary to clarify this point.

In conclusion, this study showed that skin-to-skin contact had no adverse but even positive effects on physiological parameters in preterm infants. This positive effects were especially apparent in the infants weighing < 1000 gm. Postnatal age had no measurable influence. Our results justify a further implementation of skin-to-skin contact into the routine intensive care of very immature infants.

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