Human Breast Areolae as Scent Organs: Morphological Data and Possible Involvement in Maternal-Neonatal Coadaptation

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ABSTRACT: In humans, areolar skin glands (AG) enlarge during pregnancy and lactation. Their role in mother-infant interactions may pertain to protective, mechanical, and communicative functions. It was questioned here whether more profuse AG could be related to more optimal adaptation to breastfeeding. A morphological study of the areolae was undertaken between birth and day 3 to assess the number, secretory status, and spatial distribution of AG. These data were related to infants’ weight variation, mothers’ perception of their infant’s behavior at breast, and time between delivery and onset of lactation. AG were seen in virtually all women but with great interindividual variations; their areolar distribution was nonrandom, and about 1/5 of the women had AG giving off a secretion. The AG number was positively related with neonatal weight gain between birth and day 3, and with the mother’s perception of infant’s latching speed and sucking activity. AG numbers were also positively related with the onset of lactation in first-time mothers. In conclusion, the maternal endowment in AG may contribute to the infants’ breastfeeding performance, early growth, and the mother’s lactation onset.


Keywords: human neonate; breast-feeding; colostrum; milk; lactation; areola; skin glands; olfaction; mother-infant relation

“In this circle, however narrow as it was, was studded at nearly regular intervals with the glandular tubercles, which were not unlike a ring of beads.” W. F. Montgomery, 1837.

In Mammals, the papilla (nipple) and its surrounding skin (the areola, in our own species) constitute the areas of the female’s body which enter in obligatory and recurrent contact with the newborn. The nipple-areolar structure is the result of selective shaping for the optimization of female-infant coadaptation. In addition to being the orally graspable appendage canalizing milk to the newborn, it is both the releaser of sucking in newborns and the peripheral basis that governs timely production and ejection of milk in females.

Before proper sucking is set on, the functional steps leading mammalian infants to attach to a nipple are not fully understood (e.g., Blass & Teicher, 1980). In humans, they are generally taken for granted because mothers control their infants’ placement at the breast. Despite maternal intervention, early lactation/suckling problems remain frequent, however, leading to excessive weight loss in the first postnatal days (Dewey, Nommsen-Rivers, Heinig, & Cohen, 2002, 2003), and, in the worse cases, to dehydration and threats to viability (Neifert, 2001). Nonoptimal onset of breastfeeding has been linked to various factors related to the mother (e.g., parity, nipple prehensibility, maternal...
overweight), to the infant (e.g., arousal, prandial state, competitive ingestion of heterospecific fluids), or to both (e.g., impact of delivery mode, duration of labor, labor medication; e.g., Chapman & Pérez-Escamilla, 1999; Dewey et al., 2003). The present work focuses on the potential role in the initiation of suckling of an aspect of the normal structure of the breasts, which goes generally overlooked: their endowment in skin glands.

The human female’s areolar region is of special interest because it concentrates numerous features, which, functional involvement is confined to pregnancy and lactation. Although very limited in extension, the nipple-areolar region is densely supplied with varied skin glands. The hairless nipple abounds in apocrine and sebaceous glands with ducts open on its tip to give off secretions during lactation (Montagna & MacPherson, 1974; Perkins & Miller, 1926). On the areola, eccrine glands and enlarged sebaceous glands can be found (Montagna & MacPherson, 1974). Additionally, the areolar surface is scattered with small prominences, called “follicles” or “tubercles” by Morgagni (1719) or “protuberances” by Roederer (1753). Montgomery (1837) described in more detail their macrostructure and their activation during gestation and lactation, and attested to their secretory activity (they were accordingly named “Montgomery’s tubercles” or “glands,” reviewed in Fleming, 1966). Histologically, these areolar tubercles were later confirmed to coalesce sebaceous glands and miniature mammary acini (Nae-slund, 1957; Natanson & Goldschmidt, 1909; Montagna & Yun, 1972; Smith, Peters, & Donegan, 1982). Finally, colostrum/milk released at the nipple from the main lactiferous ducts add their intrinsic olfactory qualities, viz. odorants reflecting the mother’s diet, metabolism, or genetic constitution (Schaal, 2005). Together these varied sources of substrates create a composite, highly complex odor cocktail. The lipid fraction of this mixture, sebum, originating from free sebaceous units and from Montgomery’s tubercles, may act as an odor fixative that improves the stability of the olfactory complex formed on the areolar surface (Regnier & Goodwin, 1977). The intricate arrangement of sebum and lacteal sources within Montgomery’s glands may indeed favor their mingling during sucking episodes. Finally, Haller’s subareolar vascular plexus (Mitz & Lalardie, 1977) confers to this region a higher surface temperature as compared to the nipple and to the remainder of the breast. This thermal characteristic may regulate the local evaporation rate of odorants, thereby enhancing their stimulative effectiveness. Interestingly, this thermal feature of the areola is anticipatorily triggered by the crying infant (Vuorenkoski, Wasz-Hockert, Koivisto, & Lind, 1969), resulting in optimal conditions for odor release when the infant is offered the breast. In sum, if such a localized structure, combining (i) multiple sources of odorants, (ii) lipidic fixatives, and (iii) a heat-based diffusion device, would have been described in any other mammalian species, it would have been ascribed a chemocommunicative function without much hesitation. There is more than mere speculation to that notion as applied to our own species, as numerous data have accumulated over the past decades on neonatal responsiveness to odors naturally released from the breasts of lactating women (e.g., Macfarlane, 1975; Makin & Porter, 1989; Russell, 1976; Schaal, 1986; Schaal et al., 1980; Varendi, Porter, & Winberg, 1994).

A potential communicative role of areolar skin glands (AG) may come with other basic functions. First, the increased productivity of the AG during late pregnancy and early lactation (Burton, Shuster, Cartlidge, Libman, & Martell, 1973) may add local epidermal and ductal protection from pathogens (e.g., Agache & Blanc, 1982; Gindrat, Gotheors, Hanson, & Winberg, 1972; Weisz-Carrington, 1987). Second, these greasy secretions may act to preserve the skin from the corrosive action of the nurslings’ saliva and from sucking-related stress (Perkins & Miller, 1926). Finally, skin gland secretions may combine with infant saliva to realize the hermetic seal, which makes sucking effective (Epstein, Blass, Batshaw, & Parks, 1970).

In sum, the glandular endowment of the human nipple-areolae may fulfill multiple mechanical, protective, and communicative functions. Accordingly, it may be predicted that areolae, which bear a more profuse arrangement of skin glands may facilitate the initial expression of sucking in infants and, in turn, of earlier lactation onset in mothers.

This prediction was brought to a first test in the present study. A morphological investigation of the areolae of postparturient breastfeeding mothers was undertaken. The morphological data were then related to integrative indicators of postpartal adaptation in the mother-infant dyad. On the infant’s side, adaptation was denoted as the adjustment to the numerous constraints linked with breastfeeding, such as localization of the nipple and oral grasping of it, sucking-swallowing-respiration coordination, maturation of digestive and absorptive processes, and energy conservation. It was operationalized here in terms of neonatal weight gain along the first 3 days after birth, and also in terms of the mother’s perception of their infants’ breast feeding behavior. On the mother’s side, adaptation was meant as the time elapsing between delivery and the onset of lactation, an earlier onset being beneficial to infant thriving (e.g., Dewey et al., 2003).

METHODS

Participants and Setting

Participating mother-infant dyads (n = 64) were recruited from the maternity of the Dijon University Hospital. All mothers were
of Caucasian origin and, on average, 29.3 years of age (SD: 4.2 years; range: 18–39 years). They all had healthy pregnancies and uneventful deliveries (total duration of labor: 6 ± 2.7 hr; range: 2–14 hr). Half of them were primiparae. All deliveries occurred normally through vaginal route on gestational term (40.2 ± 1.1 weeks). The newborns (31 females) were in good medical conditions at birth (Apgar scores: min 1: >8, min 5 and 10: 10) with a mean birth weight of 3396 g (SD: 427 g, range: 2600–4480 g).

The local routine for mother-infant contact goes as follows in uneventful deliveries: Right after expulsion, infants are placed on the mother’s chest for about 5 min. They are then dried, receive light suctioning of respiratory pathways and umbilical care, and are finally weighed before the first bath. They are then swaddled and laid on the mother’s chest for another 20–30 min, during which the midwife assists the first sucking episode. During subsequent 3–4 days, the newborns stay with their mothers, who are encouraged to demand-feed them (with no more than 4-hr interfeed intervals). The infants receive complementary formula milk if breast milk intake is judged insufficient by the midwives. After each feeding bout, mothers are advised to simply wipe their areolae and nipple with a scentless, humid gauze pad. Seventeen of these mothers applied a prophylactic pomade on their nipples (Bepanthe`ne<sup>®</sup>, Roche, Basel, Switzerland). In this case, they were required to put this pomade only on the nipple (see below, Data Analysis section).

The participating mother-infant dyads were recruited within the 24 hr following delivery. The mothers were informed of the methods of the study but were blind to the specific hypotheses under test. If the inclusion criteria were fulfilled (normal pregnancy and delivery, breastfeeding intention, absence of lactation-related disorders, normal nipple conformation, no smoking), the mothers signed an informed consent form to participate.

Data Collection

Background informations about pregnancy and delivery were collected from the mother (time to, and duration of, first contact and first breastfeeding, first-sucking behavior) and from her medical record (parity status, total duration of labor (onset of regular contractions to expulsion), mode of delivery, labor medications, infant Apgar score, and birth weight).

Areolar Morphology.

To deal with their modesty, the mothers were enrolled in the inspection of their areolae. This self-inspection was standardized through precise instructions. The mothers were required to report daily informations about their areolar glands on a diary in which they had to fill out predesigned schemes and items. The first inspection was made by a midwife and an experimenter on postpartum day 0 (0–24 hr). The areolar measures were made during the 3–4 days in the maternity. These measures were made on average 2.3 ± 0.9 hr after the last feed, with an interval of 23.9 ± 1.6 hr between two reports. The following areolar variables were collected:

1. The **nipple-areolar surface** was assessed in using a template consisting in a plaque of transparent Perspex perforated with nine circles (diameter: 40–80 mm, steps of 5 mm). The areolar surface was defined as the circle of the template best fitting the limits of the pigmented skin. The surface of the nipple’s base was estimated with another such template bearing 11 circles (diameter: 10–30 mm, steps of 2 mm). The final areolar surface (in cm<sup>2</sup>) was obtained by subtracting nipple surface from nipple + areolar surface.

2. The **number of AG** was recorded after extensive training of the mothers to recognize the variety of structures of human areolar surface. The mothers were presented with photographs of areolae with different morphologies. They were taught that areolar skin structures of various levels of elevation (up to 1 mm) and pigmentation could be seen (Fig. 1A,B). Previous histo-morphological studies had noted the variability in terms of height or pigmental contrast of areolar structures (Montgomery, 1837; Montagna & Yun, 1972; Montagna & MacPherson, 1974). Regardless of these surface features of the areolar glands, histological studies found that they all combined sebaceous units and lactiferous lobules (Giacometti & Montagna, 1962; Montagna & MacPherson, 1974; Smith et al., 1982). We assumed thus that any visible structure on the areolae was of interest in terms of potential secretory output, and considered that mothers were not required to differentiate among them.

![FIGURE 1](image.png) (A) Photograph of an areola (left breast, postpartum day 3), showing (arrows) skin structures (revealed by relative elevation and pigmental heterogeneity relative to surrounding skin), which were counted as areolar glands. (B) Enlarged (2.5×) view of an areolar gland. (C) An areolar gland giving off a milk-like secretion during a breastfeeding. (D) Enlarged (3×) representation of a secretory drop from an areolar gland.
Every pigmented skin elevation, termed “areolar gland” (AG), was then reported on predefined schemata of the areolae. The mothers additionally had to report whether some fluid came out at the tip of these AG (Fig. 1C,D). From the mothers’ precise reports, the position of the AG was located on the four quarters (Q1–Q4) of their areolae defined by the virtual vertical and horizontal lines crossing on the tip of their nipples (demarcating upper lateral/medial, and lower lateral/medial quarters; cf. schemes on Fig. 2C,D).

In some mothers (n = 21, observers 1) who were tolerant to the presence of the experimenter (observer 2), a record of the AG could be directly established. As these women complied to let their areolae be photographed, an additional coding could be made by a 3rd observer who was unaware of the aims of the study. Interobserver reliabilities for the areolar structure notation were assessed by Spearman correlations. The correlations for the total numbers of AG were (for the right and left breast, respectively) .96 and .97 between observers 1 and 2, .86 and .92 between observers 1 and 3, and .76 and .87 for observers 2 and 3 (p < .0001 in all cases). For the spatial location of these AG on the four areolar quarters defined above the correlations reached (for Q1, Q2, Q3, and Q4, respectively) .92, .89, .96, and .91 between observers 1 and 2, .91, .88, .84, and .83 between observers 1 and 3, and .84, .81, .91, and .89 for observers 2 and 3 (p < .0001 in all cases). It may thus be concluded that the mothers’ records of their AG were highly reliable for both total number and location on the areolae.

Thus, the outcome variables were AG number, secretory status, and spatial position on the areolar surface. For each participating mother, the mean AG number from each areola made on days 1 (24–48 hr) to 3 (72–96 hr) postpartum will be subjected to analyses. A subset of 29 women from the total sample of 64 were home-visited by the experimenter (SD) and a midwife (EH) to follow up the reporting of their AG on days 15 and 30.

FIGURE 2 (A) Mean (±SEM) areolar surface during postpartum days 1–3 to 30 (n = 29 women). (B) Frequency distribution of mean areolar gland number between birth and postpartum day 3 (n = 64 women). The photographic inserts show the two extreme pictures of areolar gland endowment. (C) Spatial distribution of mean (±SEM) areolar gland number in the four quarters defined by the virtual vertical and horizontal lines crossing at the nipples’ tip (n = 64 women). (D) Spatial distribution of mean (±SEM) areolar gland number giving off an obvious secretion in the four quarters defined by the virtual vertical and horizontal lines crossing at the nipples’ tip (n = 12 women). In all cases, different letters indicate statistically significant differences.
**Infant Weighing.** Infants were weighed on a mechanical scale (Testut, type 279; precision: 5 g) by experienced nurses who were blind to the hypotheses of the study. The birthweight was obtained after delivery and before the first breastfeeding. The daily weights were obtained while the infants were bare, right prior to bath and feeding on days 1–3 between 7.00 and 11.00 am. The reliability of the weighing procedure was established by 3 persons who weighed the same 12 infants three times. Pearson correlations indicated very high repeatability of weighing ($r > .98$ in all cases). The percent of daily weight variation (DWV) between birth and day 3 postpartum was computed using the following formula, ($W_0 - W_3/3)/W_0 \times 100$, where $W_0$ is the birth weight and $W_3$ the weight on day 3 (mean age: 73.20 ± 6.35 hr).

**Lactation Onset.** Lactation onset was assessed twice per day at 12-hr intervals. Several cues were noted by the midwives after direct breast palpation (such as softness and milk oozing from the nipple after weak pressure), and after a maternal interview about sensations of breast tension, warmth, or pain (Chapman & Pérez-Escamilla, 2000a,b; Pérez-Escamilla & Chapman, 2001). The time of lactation onset was determined as the day when the female’s breast activity criteria were reported positively on three consecutive nursing periods.

**Maternal Reports on Infant Behavior at the Breast.** At the end of every day (7.00–9.00 pm) between days 1 and 3, under the supervision of the experimenter, the mothers were asked to rate their perception of the infant’s responses at each breast during the nursing bouts of the current day. Neonatal presucking and sucking responses were assessed through a four-item questionnaire. Two items related to the mothers’ perception of their infant’s preigestive behavior: (1) “When you put the baby onto your breast, does s/he express alternating, lateral rooting movements”? (answer range from “not at all” to “yes, a lot”). (2) “How fast does your baby take the nipple in mouth”? (answer range from “very slowly” to “very fast, immediately”). Two items intended to evaluate the infants’ responses after oral seizing of the nipple. (3) “When the baby has grasped the nipple, does s/he suck”? (answer between “very slowly” and “very fast, immediately”); (4) “How does the baby generally behave during breast-feeding”? (answer range: “drowsy, sleepy” to “very active”). The responses to these items consisted of putting a cross on 10-cm visual analogue line scales on which extremes are denoted as above. The mothers’ perception of their infant’s behavior was coded between 0 and 10 separately for each breast. The outcome variable was the average of a given item scores for each breast and then the average over the day 1–3 period. A global score of maternal perception of infant sucking behavior was obtained by the aggregation of the four items.

**Data Analyses**

The morphological reports on the areolae were obtained from the whole sample of 64 postparturient women between birth and day 3. Among the 64 newborns, 35 were exclusively breastfed (group $f_0$), 9 received formula once (<15 mL; group $f_1$), and 20 received formula on several occasions (2–8 times, range of ingested volume: 40–250 mL; group $f_+$.). The decision to formula-feed the infants was on the side of the maternity staff or required by the mother in case of extreme tiredness. This early formula-supplementation appeared to influence infant growth and maternal lactational dynamics between birth and day 3. The $f_+$ newborns had a (nonsignificant) higher daily weight loss as compared to the $f_0$ and $f_1$ newborns ($-1.68 \pm .73$, $-1.31 \pm .85$, and $-1.25 \pm .59$%, respectively; ANOVA; $F(2,61) = 1.63; p = .21$). In addition, the mothers of $f_+$ infants had a later lactation onset as compared with the two other groups of mothers (group $f_+ + 3.0 \pm .7$ days; group $f_0 + 2.4 \pm .5$ days; group $f_1 + 2.4 \pm .7$ days; ANOVA; $F(2,61) = 5.45; p < .01$; Tuckey’s test: $f_+ vs. f_0$: $p = .009; f_+ vs. f_1$: $p = .036; f_0 vs. f_1$: $p = .99$). Thus, the $f_+$ mother-infant dyads were discarded from the analyses on the relations between areolar morphology, infant growth, and lactation onset. It may be noted that, as compared to the remaining 44 mother-infant dyads ($f_0 + f_1$), the 20 $f_+$ mother-infant pairs who were partially discarded from the analyses were not statistically different on maternal AG number, age, parity, gestation length, labor duration, or infant birth weight, and sex.

Among these 44 women-infant pairs, 17 applied prophylactic pomade onto their nipples. However, this practice affected neither the newborns’ DWV (mean ± SD: $-1.27 \pm .76$% (no pomade, $n = 27$) vs. $-1.31 \pm .81$% (pomade, $n = 17$); $F(1,42) = .18$), nor the timing of lactation onset (mean ± SD: 2.35 ± .61 days (no pomade, $n = 27$) vs. 2.41 ± .50 days (pomade, $n = 17$); $F(1,42) = .22; p > .05$, in both cases).

Finally, the relations between areolar morphology and infant behavior at the breast were derived from a subsample of 17 mother-infant pairs. Among these 17 women, 6 applied pomade only on their nipples, a practice which again does not influence the global score of the mothers’ perception of their newborns’ behavior at the breast (no pomade ($n = 11$): 24.5 ± 3.6 vs. pomade ($n = 6$): 24.2 ± 4.0; Kruskal–Wallis test, $H(1,17) = .24; p = .63$).

The total group of 64 mother-infant dyads and the subgroups deriving from it (i.e., $n = 44, 29$, and 17) were not statistically different on maternal age, parity, gestation length, labor duration, and infant birth weight and sex ratio. It is important to note that these different subgroups did not result from a priori selection among the total group of 64 mothers, but from sequential recruitment driven by incoming research questions in the present exploratory study.

The longitudinal follow-up of the areolar surface on postpartum days 1, 2, 3, 15, and 30 was analyzed by conducting 2-way repeated-measures analyses of variance (ANOVA) on mean AG number and mean secretory AG number, with days (5 alternatives) and side (2) as the within-subjects variables. The distribution of AG on each quarter of the areolae was compared through a 1-way ANOVA with quarter (4) as the within-subject variable. A 2-way ANOVA was carried out on mean AG numbers with parity (2) and sex (2) as the between subjects and variables. Relations between distinct-dependent variables (AG numbers, areolar surface, duration of labor, DWV, delay of lactation onset, scores of maternal perception of infant behavior) were analyzed with the Pearson product–moment correlation coefficient. Prior analyses attested that these variables were all normally distributed (Kolmogorov–Smirnov’s test; $p > .20$ in all cases).
RESULTS

Morphological Data

The mean areolar surface in the present sample of 64 postparturient women was 24.44 ± 9.16 cm² (range: 6.41–47.17 cm²). Mean areolar surfaces were nearly equivalent on the left and right breast (means ± SD: 24.53 ± 9.06 and 24.36 ± 9.51 cm², respectively). The follow-up study on 29 women revealed that the areolar surface changed across the first postpartum month ($F(4,280) = 5.47, p < .01$), with a significant increase on day 3 (as compared to days 1–2; Tuckey tests, $p < .05$; cf. Fig. 2A).

The whole sample of 64 women revealed both the general presence and the high numeric variability of AG between individuals. All but one women (98.4%) had areolae endowed with AG, and the majority (83%) evinced between 1 and 15 AG on each areola (Fig. 2B). The mean number of AG per areola was $8.9 ± 5.6$ (range: 0–38) for the whole sample. In the subgroup of 29 women followed-up from birth to day 30, the mean number of AG was stable ($F(4,280) = .146, p = .96$). In addition, the AG number was unrelated with areolar surface (Pearson’s $r = .13, n = 64, p > .05$), and similar between the left and right breast ($F(1,280) = .30, p = .58$; mean ± SD: left: $9.0 ± 9.19$ vs. right: $8.8 ± 9.05$). However, their spatial distribution on the areolae appeared to be heterogeneous ($F(3,124) = 2.67, p < .05$). In the four areolar quadrants defined in the Methods section, the upper lateral and medial sectors and the lower lateral sector were equivalent in average AG equipment ($2.51 ± 1.84$; $2.20 ± 1.83$; $2.26 ± 1.65$, respectively), but higher than the lower medial sector ($1.85 ± 1.8$) (Tukey tests, $p < .05$; Fig. 2C).

When looking at the secretory status of the AG, 12 out of the 64 mothers bore at least one AG giving off a small amount of latescent fluid. Thus, in the present conditions of areolar inspection, 18.7% of the mothers reported to have emerged a visible fluid emission from the AG. Among these 12 women, 6 had 1 secretory AG, 3 had 2, and 3 had 3–4. The areolar repartition of these discernibly secretory AG was not random on the areolar surface, $F(3,92) = 2.71, p < .05$. The upper lateral sector was more frequently observed to bear secretory AG (.19 ± .33) as compared with the three remaining sectors (upper medial: .1 ± .14; lower lateral: .05 ± .12; lower medial: .05 ± .1) (Fig. 2D).

Finally several factors, which may influence areolar variables, were examined. Parity was assessed because it is known to affect the duration of labor (Agboola & Agode, 1976), and duration of labor because it affects the postpartal delay to lactation onset (Dogana & Avsor, 2002). The sex of the fetus further influences the maternal level of circulating androgens (e.g., Resko, 1970; Meulenberg & Hofman, 1991) and may thus affect differentiation or activity of sebaceous glands in general (Kiraly, Collan, & Alen, 1987; Petersen, Zone, & Krueger, 1984), and of the sebaceous component of the AG in particular. However, none of these factors had a significant influence on areolar surface, AG number, or AG activity.

Areal Gland Number and Infant Growth

Neonatal weight fluctuations followed from birth to postpartum day 3 (in the subsample of 44 infants) were highly variable between and within subjects. The weight variation averaged $-46 ± 26$ g/day, with a mean weight variation of 138 g (i.e., 4.2% of birth weight). This neonatal weight variation was unrelated to infant sex or labor duration; but it was positively related to the mother’s number in AG ($r = .57, p < .005$). That is, infants of mothers bearing a higher AG endowment evinced a lesser weight loss between birth and Day 3.

Prior childbearing experience is known to strongly influence maternal variables related to lactation and to nursing abilities (e.g., Fleming, 1990; Krasnegor & Bridges, 1990; Trevathan, 1987). Therefore, we addressed whether the mothers’ parity status could be a mediating factor between her AG number and structure, and the newborn’s DWV. We compared the DWV of four subgroups of newborns contrasted for mother’s parity and AG number: (1) infants from multiparous mothers with mean AG number that was higher or equal to the median of the whole sample (8.5 glands) (abbreviated “P + G+”, $n = 14$); (2) infants from multiparous mothers bearing less than the median AG (“P + G−”, $n = 9$); (3) infants from primiparous mothers having AG numbers higher or equal to the median (“P − G+”, $n = 11$); and (4) infants of primiparous mothers having AG numbers lower than the median (“P − G−”, $n = 10$). These four groups were not statistically different regarding infants’ gestational age, birth weight, duration of labor, (1-way ANOVAs; $F(3,40) = 1.02, 1.06$, and 1.76, respectively; $p > .10$ in all cases), and sex ratio. A 2-way (parity by AG number) ANOVA indicated a main effect of AG number on DWV ($F(1,42) = 25.31; p < .001$). The newborns of mothers having higher AG numbers evinced lower DWV between birth and postpartum day 3 (−.82 ± .58%) as compared to infants of mothers having lower AG numbers (−1.79 ± 6.4%). However, no main effect of parity or parity by AG number interaction on infants’ DWV reached significance ($F(1,42) = .009$ and 2.01; $p > .05$ in both cases).

Areal Gland Number and Onset of Lactation

Since lactational physiology is influenced by parity (Hildebrandt, 1999), we assessed the influence of parity on the postnatal latency to onset of lactation. The DWV between birth and day 3 was negatively correlated with
time of lactation onset (−.57, p < .005), indicating that an earlier weight recuperation in newborns is linked to an earlier lactation onset. The comparison of lactation onset in the four above groups of mothers evidenced marginal main effects of parity and AG number. Lactation set on later in primiparae (2.7 ± .4 days) than in multiparae (2.4 ± .6 days) (F(1,42) = 3.09; p = .09), and in women with low AG numbers (2.8 ± .5 days) as compared to mothers with high AG numbers (2.4 ± .4 days) (F(1,42) = 3.86; p = .06). However, a significant parity by AG number interaction was reached (F(1,42) = 6.22, p < .05), indicating that lactation was set on later in P−G− mothers (3.1 ± .6 days) than in P+G+, P+G− and P−G+ mothers (2.4 ± .5; 2.4 ± .7, and 2.3 ± .5 days; Tuckey tests, p < .05, p < .08, and p < .08, respectively).

Areolar Gland Number and Maternal Perception of Neonatal Suckling Behavior

The mothers’ perception of their infants’ behavior at the breast was associated with AG number in several ways. First, AG number was correlated negatively with the mother’s perception of rooting duration (r = −.61, n = 17, p < .05; Fig. 3A) and positively with her perception of nipple grasping speed (r = .55, p < .05; Fig. 3B). Second, the number of AG was positively correlated with the mother-reported intensity of sucking (r = .40, p < .05; Fig. 3C). Thus, the mothers’ endowment in AG seemed to be linked with presucking and sucking activity in newborns. Finally, the global score of mother’s perception of infant activity at the breast was positively correlated with AG number (r = .69, p < .05).

The mammary gland undergoes physiological changes over the first week postpartum, colostrum being progressively replaced by milk (Neville, 1995). Since areolar glands are in part composed of miniature milk acini (e.g., Montagna & MacPherson, 1974), one may expect that the quality of their secretion changes as well, and that such changes may be perceivable to nurslings. To evaluate such a possibility, the correlations between AG number and the four behavior items were examined daily over. The mean AG number was correlated: (i) negatively with the mother-reported frequency of rooting activity on days 1 and 2, but no more on day 3 (r = −.56, −.50, and −.36; p < .01, <.05, and >.05, respectively); (ii) positively with the speed of nipple grasping on days 2 and 3 (r = .49 and .56, p < .05); and (iii) with the score of sucking intensity on day 1 (r = .64, p < .01). Thus, mothers who are more affluent in AG tend to report shorter latencies to their infants’ nipple seizing and higher sucking activity, but these relations appear to be stronger on the first postnatal days.

Otherwise, it may be noted that the global score of infant activity at the breast was affected by the mother’s parity: primiparous mothers evinced a lower global score of infant behavior at the breast than multiparous mothers (21.2 ± 2.1 vs. 26.5 ± 2.2; Kruskal–Wallis test, H(1,17) = 5.12; p < .05).

DISCUSSION

Areolar Morphology

The present study conveys new results on the morphology and activity of areolar exocrine structures in lactating women. To the best of our knowledge, AG have never been examined quantitatively during the period when breastfeeding is established. In the present study, the majority of subjects (98.4%) bore more than 1 AG, and 83% bore 1–15 AG on each areola. Only one subject of the present sample was devoid of any apparent AG. Montgomery (1837) first reported 12–20 glands per areola in pregnant women, and Smith et al., 1982 noted 1–5 in postmenopausal women (a discrepancy which may be related to alterations in AG prominence and pigmentation outside of pregnancy/lactation; Montagna & MacPherson, 1974). In the same line, no study could be located on the intrindividual variation of the secretory activity of these glands. Among others, Montgomery (1837); reviewed in Natanson & Goldschmidt (1909), Ackerman & Penneys (1971) and Montagna & Yun (1972).

FIGURE 3 Distribution of average scores of maternal perception of infants’ (A) rooting duration, (B) nipple grasping speed, and (C) sucking intensity as a function of mothers’ areolar gland numbers (n = 17 mother-infant dyads).
observed a visible oozing of areolar fluid during nursing. The present study adds that about one out of five women give off a whitish fluid between two nursing bouts. This proportion may be underestimated, however, as the present AG censuses were made amid two nursing sessions. It may be expected that distal (crying) or proximal (sucking) infant signals would trigger more copious milk release in the lactiferous component of AG, as they massively do in the main mammary glands (Noel, Suh, & Frantz, 1974).

The between-subject variability in AG number and secretory activity may be balanced by a nonrandom spatial distribution of AG in general, and in particular of AG giving off an obvious secretion. Several possible functions of AG were outlined in the Introduction, including protective, mechanical, and communicative aspects. These varied functions may relate differentially to the spatial arrangement of AG on the areolae. Protective functions would imply uniform AG distribution over the areolar surface to avoid mammary/neonatal colonization by pathogens. Alternatively, protection from corrosive effects of dribbling infant saliva would recruit heightened AG density on the lower part of the areolae. An involvement of skin secretions in creating the sucking-seal would further direct an even repartition of the AG, whereas a communicative function would favor a distributional bias to the upper half of the areolae to which the infants’ noses are directed. If all the above overlapping functions would have equivalent significance in nursing, one may predict a homogeneous areolar distribution of AG. However, the present results reveal that AGs are not evenly distributed over the areolae. Although some of them can be seen on the whole areolar disk, AG and secretory AG dot more frequently the upper, and especially the upper lateral, quarters. As these areolar quarters are also those to which the nurslings’ noses are most frequently directed, one may suggest that the local arrangement of AG might be predominantly driven by communicative functions.

If the areolae support a communicative function, one may further expect an increase in the secretory output of the AG (i) right after delivery, and (ii) right before each nursing bout. Only suggestive data in favor of point (i) were obtained here as more women tended to evince secretory AG on days 1–3 than on days 15 or 30. But more definitive conclusions on these points await areolar inspections made right before and during nursing under maximal stimulation from infants.

**Areolar Structure and Adaptive Outcomes in Infants and Mothers**

According to the rationale exposed in the Introduction, it was hypothesized that infants born to mothers with higher AG endowment would demonstrate improved adjustment to the challenges represented by the initial breastfeeding. The mother’s AG number was indeed linked with two neonatal outcomes, the infants’ DWV over the first 3 postnatal days and the mothers’ perception of their behavior while nursing. Regarding the DWV, the average neonatal weight loss recorded here was within the range considered normal in other studies (Dewey et al., 2003; Maisels, Gifford, Antle, & Leib, 1988; Manganaro, Mami, Marrone, Marsiglia, & Gemelli, 2001). Within these limits, the total AG number correlated positively with the infants’ DWV between birth and day 3, lending support to the hypothesis that a higher AG number is beneficial to early thriving. Otherwise, the relation between the mothers’ AG number and ratings of infant behavior at the breast was preliminarily examined here in a subsample of participants. It came out that the mothers’ perception of their infants’ sucking responses was significantly linked with their endowment in AG. Within the birth-to-day 3 period, infants from mothers having more profuse AG were reported to latch on more rapidly, and to be more active suckers after latching. These data designate AG quantity as one potential promoter of infant arousal and sucking responses at the breast.

In humans and other mammals, parity impinges on all psychobiological aspects of parental investment, viz. mammary morphology and physiology, brain function, and nursing and caring behavior (e.g., Fleming, 1990; Krasnegor & Bridges, 1990; Trevathan, 1987). For example, mothers who have breastfed a first infant evince more protractile nipples, making them moreprehensible for subsequent newborns (Gunther, 1955; Hytten & Baird, 1958). Parity also affects the postnatal dynamics of lactogenesis and the amount of milk produced (Hildebrandt, 1999; Ingram, Woolridge, Greenwood, & McGrath, 1999; Zuppa et al., 1988). Finally, maternal behavior varies as a function of parity in the sense that, during the first postpartum days, multiparous mothers react more adequately to infant signals, exhibit more proximal contact behaviors and have better mastery in instrumental care of the infant. Regarding breastfeeding, multiparous are more prone than new mothers to offer the breast when their infant cries, and are then more skilled at appropriately positioning the infant (Bernal, 1972; Bleichfeld & Moelly, 1984; Thoman, Turner, Leiderman, & Barnett, 1970; Thoman, Leiderman, & Olson, 1972; Trevathan, 1987). Accordingly, primiparity is generally associated with less optimal initial nursing interactions, delayed onset of lactation, lower milk yield and excess weight variation in neonates (Dewey et al., 2003; see also Chen, Nommensen-Rivers, Dewey, & Lönnerdal, 1998; Hildebrandt, 1999; Ingram et al., 1999; Manganaro et al., 2001). The present data do not corroborate the impact of parity on postnatal weight variation, but they do so on the link between parity and the timing to lactation onset.
Overall, multiparous mothers evinced a shorter latency to lactation onset as compared to primiparous mothers. The inception of lactation was associated with the maternal endowment in AG in first-time mothers, but it was not in multiparous mothers, indicating that infants of new mothers reacted more, as a group, to a higher AG number. These latter infants being in theory exposed to less expert maternal guidance to the breast, it may be hypothesized that they need to rely more on their own sensory and motor keenness to achieve successful nipple localization and latching. In this context, primiparous mothers endowed with more AG (compared with primiparae endowed with less AG) may offer their infant more helpful (chemo) sensory guidance to the nipple.

The causal pathways linking maternal AG endowment to infant weight variation during the first postpartum days remain to be determined. AG may affect directly the organization of neonatal behavior at the breast, and indirectly maternal behavior and lactational physiology. On the one hand, infants from mothers bearing higher AG numbers were reported to latch-on more easily and to suck more intensely, all variables which may result in more efficient colostrum intake. Such facilitation may in turn be beneficial to mothers (especially to primiparae) as self-reassurance in breastfeeding ability. On the other hand, facilitated sucking of areolae bearing higher AG numbers is associated with more effective nipple stimulation, which is causal to earlier onset of lactation (Aono, Shioji, Shodfa, & Kuratchi, 1977; Dewey et al., 2003; Howie, McNeilly, McArdle, Smart, & Houston, 1980). Although this nexus of causal relationships remains to be further substantiated, the present study provides some clues on the possible involvement of skin glands of the lactating human breast in the adaptive mother-infant transactions at the onset of their postnatal relationship.

NOTES

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