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A brief history of antenatal colostrum expression, and where to from here

Therese A. O'Sullivan* and Connie N. Ihlein

Nutrition & Health Innovation Research Institute, School of Medical and Health Sciences, Nutrition & Health Innovation Research Institute, School of Medical and Health Sciences, Edith Cowan University, Joondalup, WA, Australia

The practice of antenatal colostrum expression (ACE), or the extraction of colostrum from the breasts during pregnancy, has an interesting history and continues to evolve. This narrative review aims to describe how perception and practices of ACE have changed over time, summarise the evidence on ACE in maternal and infant care, and highlight areas for future research. The literature demonstrates that ACE is safe for low-risk women when done from around 36 weeks' gestation. Women should be reassured that the skill of hand expressing is a valuable tool post-birth, regardless of whether they are able to collect colostrum antenatally or not. The collection and storage of colostrum in pregnancy can help avoid formula use in hospital, which may have follow on effects immune function and other areas. Ideally, colostrum collected during pregnancy would be kept safely frozen during the hospital stay and only defrosted and used during the stay if medically indicated, with parents supported through that process. Although ACE does not appear to improve long-term breastfeeding rates at present, it can increase confidence around breastfeeding. Further research in more diverse population groups, long-term breastfeeding and long-term health outcomes of using frozen antenatally expressed colostrum for babies (as compared to formula or fresh colostrum) would be valuable to gain a better understanding of the importance of ACE in maternity care.

Keywords: Pregnancy: Antenatal expressing: Colostrum: Breastfeeding

Colostrum is an amazing fluid. As we learn more about the benefits of colostrum, interest in expression, storage and use of antenatal colostrum is growing. This narrative review aims to explore how research investigating antenatal colostrum expression has evolved, summarise the evidence to date and highlight areas for future study.

Colostrum has been referred to as 'the golden milk for infants' health'[1], reflecting both its yellowish colour and the nutritional composition, rich in developmental and immunological factors[2]. Colostrum is the first milk produced by a pregnant mother, created by the alveolar cells of the breast as early as the second trimester of gestation[3]. It provides the first nutrition for the newborn for up to around three days after birth, after which time there is a change to transitional milk for approximately two weeks, followed by production of mature milk.

Being fed colostrum for the first few days of life has many benefits which are now more well known. Although the function of the breasts is to produce milk to feed infants, the purpose of colostrum specifically is to provide a concentrated, low-volume milk. This thick fluid assists the newborn in mastering the coordination of

***Corresponding author:** Therese A. O'Sullivan, email: t.osullivan@ecu.edu.au

sucking, swallowing and breathing necessary during breastfeeding[3]. Nutritionally, human colostrum is the perfect food for human newborns. It is richer in protein than mature breast milk, with protein concentration estimated at 14–16 g/l during early lactation and then halving to 7–8 g/l at six months onwards with mature milk[4].

One particular protein that is high in colostrum is immunoglobulin A, which is one of the most common types of antibodies in the body and helps protect against infection[3]. Secretory immunoglobulin A transfers the mother's immunity against some general pathogens to her breastfed infant, enhancing the immature immune system of newborns through their mothers acquired immunity[4].

Emerging evidence from mouse models of colostrum deprivation demonstrates the importance of colostrum for gut immune development[5]. Mouse pups nursed immediately after birth by dams producing mature milk, rather than colostrum, had severely compromised expansion of a cell type important in gut immune regulation (ILC2) compared with control pups. These colostrum-deprived pups also showed a decreased ability to control an intestinal worm infection at three weeks of age (roughly equivalent to a 3-year-old toddler in human years)[5], indicating the ability for early colostrum feeding to establish the foundations for a healthy immune system later in life.

Colostrum expression

Although the value of colostrum is undisputed, in some traditional cultures the unusual colour, texture and smell of colostrum compared to mature milk led people to think that it was not safe or appropriate for newborns to consume (Wickes 1953). Thus, colostrum expressing was initially performed in order to discard the colostrum, to avoid newborn infants consuming it for the first few days of life.

Anthropologists and ethnographers have documented colostrum taboos across different cultures[6], and unfortunately, the practice of colostrum avoidance still exists at time of writing. For example, one in five breastfeeding mothers were found to discard colostrum in Ethiopia[7]. The most influential individuals for colostrum avoidance in this study were grandmothers and traditional birth attendants, indicating the effect of traditional taboos passed down from previous generations. It was believed that colostrum could not be digested properly. As a result, butter, cow's milk or water was given instead of human colostrum for the first few days post-birth[7]. Similar findings of colostrum avoidance have been observed in other countries including Nigeria[8], Guatemala[9], Egypt[10] and India[11]. Instead of consuming colostrum, various liquids including sugar water, coconut water, honey, alcohol, castor oil and cow's milk are among examples that have been previously documented in Asia, Africa or Latin America in order to either to 'purify and clear' or to 'prepare the baby for adult life'[12].

These taboos persist despite evidence to the contrary, even evidence within the same cultures. For example, in Ethiopia, newborns deprived of colostrum were more likely to have stunted growth compared to those who received colostrum[13]. Given the agreement in the literature that colostrum is a highly valuable and nutritious milk to support optional infant health, it is hoped that the practice of expressing and discarding colostrum will cease in the near future.

Expressing of colostrum antenatally

Antenatal colostrum expression (ACE) was originally performed as a means of preparing the breasts for breastfeeding after birth. The first person to popularise ACE is noted as the British doctor Harold Waller in the 1940s, who aimed to investigate and address causes of early breastfeeding difficulties[14]. Waller believed that women who were taught and practiced the skill of hand expression during pregnancy could use it post-birth to help manage breast engorgement. Antenatal massage and expression of colostrum also had the intention of strengthening the nipples and avoiding obstruction of the ducts.

In the British Hospital for Mothers and Babies, Woolwich, Waller conducted a study of 200 nulliparous women alternately allocated to either an ACE intervention for the last three months of pregnancy (around 28 weeks gestation) or a control group[14]. Glass nipple shields were also used for women in either group during pregnancy to help draw out inverted nipples. After birth, women in the intervention group were encouraged to manually express out any 'leftover' milk in the breast after feeding their babies. The intervention itself was referred to by later researchers as the 'Woolwich method' or regime[15,16].

The project was initially planned to include 200 women in each group, double the number actually included. However, due to war-related bombing, women in late pregnancy were more likely to be in the provinces, and in hospital mothers had to be regularly moved to the basement for safety, which interfered with data collection[14]. The study therefore may have been underpowered.

Despite this, Waller's initial results seemed promising. Women in the intervention group reported substantially lower rates of engorgement with obstruction (5 mothers compared to 19), lower rates of nipple injury (12 *v.* 24) and higher rates of wholly breastfeeding at six months (83 *v.* 42)[14]. Although this early study seemed encouraging, other researchers have noted some important limitations to Waller's research[17]. For women with engorgement problems, hand expression of breast milk after feeds was routinely used and some mothers were given stilboestrol, a synthetic oestrogen, to inhibit lactation. Stilboestrol use was subsequently discontinued due to concerns around efficacy and safety and was banned by the United States Food and Drug Administration in 2000[18]. The published manuscript did not record how many women from each group received these treatments. In addition, the intervention group received additional support from a midwife both antenatally and postnatally, which may have contributed to improved breastfeeding rates in this group[17].

A replication of Waller's study was conducted by John Blaikley and colleagues in Guy's Hospital, London and published in 1953[15]. The intervention was slightly

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different, in that massage of the breasts and expression of colostrum was only started from around 32–36 weeks gestation (as compared to around 28 weeks). Similar results were found in Waller's study – women in the intervention group who performed ACE were significantly more likely to be breastfeeding their infants at 6 months of age compared to the control group (53 *v.* 26%, respectively)[15]. However, this difference in long-term breastfeeding was only for women with hospital births, not for women who birthed at home, and the researchers concluded that post-birth support provided was more important than the support provided during the antenatal period[15]. The value of ACE was determined to be *learning the skill* of hand expressing to apply post-birth if required, rather than the physicality of expressing colostrum in pregnancy.

Further doubt was cast over the Woolwich method in the late 1950s. Research in Stockholm by Axel Ingelman-Sundberg investigated antenatal breast massage and colostrum expression from the 20th week of pregnancy, in conjunction with manual expression of residual milk following breastfeeding after the baby was born[16]. There were 313 women in the intervention group and 343 in the control group. Rates of full breastfeeding upon discharge from hospital (one-week post-birth) were similar between intervention and control women (94 *v.* 93%, respectively). They do not seem to have been followed up past this point. These breastfeeding rates were higher than observed in Britain at around the same time, with Waller quoting 80% in a 1944 Ministry of Health report as background to his work[14]. Ingelman-Sundberg also investigated mastitis in the Stockholm study, noting a concerning trend: 'The frequency of mastitis during the stay in hospital was 0.88 ± 0.51 per cent among the controls and 2.88 ± 0.95 among the antenatally treated patients, the *P*-value of the difference being less than 0.06'. (Note there is very little detail given about this variable in the original article - it is described as a 'frequency of mastitis' and given in units of 'per cent'. We are not certain if this means the percentage of women affected or something to do with the number of times during the week. We have used a direct quote so readers can make up their own mind.) Ingelman-Sundberg concluded that ACE was of little value as a routine treatment, although noted that it may be helpful for women with inverted nipples.

It is interesting to note that ACE was not practiced in isolation with these studies, but expression post-breastfeeding was also performed by the mothers. Given the supply-demand principle of lactation, it is likely that hand-expressing additional milk after feeds led to a greater milk supply than was required. This may have contributed to higher rates of engorgement and mastitis, potentially explaining the results observed by Ingelman-Sundberg[16].

A move away from ACE

During the 50 years that followed, few studies were conducted on ACE – those that were conducted generally had low participant numbers (<100), often with inadequate explanation of how sample size was determined. Other substantial limitations included a lack of reliable, validated tools, a lack of ethics approval documentation and ambiguous randomisation procedures[19]. Studies on ACE and other forms of breast preparation during pregnancy did not show much benefit for breastfeeding, and by the early 1990s breast preparation during pregnancy was no longer recommended[19].

Issues with safety were also raised, particularly in regard to ACE leading to early labour[19]. There were concerns about breast stimulation leading to the release of oxytocin, a hormone that helps milk in the breasts to flow and fill the ducts for breastfeeding. The same hormone also stimulates uterine contractions in labour during childbirth (and after birth). There were concerns that ACE could trigger premature labour[19].

In a Cochrane review of the literature[20], the relationship between breast stimulation (not ACE per se) and birth outcomes including inducement of labour was reported from over 600 participants across five trials. Analysis of trials comparing breast stimulation with no intervention in term women (from 37 to 42 weeks gestation) found that women performing breast stimulation were more likely to be in labour after 72 hours – the proportion not in labour was 62.7% for the stimulation group versus 93.6% for the control group. This was considered a beneficial result due to the women being considered full-term and being able to avoid induction of labour. A reduction in postpartum haemorrhage rates was also observed for the breast stimulation group, with no significant differences in the caesarean section rate. The authors recommended more research to further investigate these findings[20].

In addition, breastfeeding (and therefore resulting breast stimulation) during pregnancy appears to be unrelated to adverse outcomes in low-risk pregnancies, although more research is required[21]. Likewise, it has been shown that less oxytocin is released in response to breast stimulation *during* pregnancy than when a woman is not pregnant[22]. Taken as a whole, the literature suggests that it is unlikely that oxytocin released during pregnancy from breast stimulation will lead to adverse outcomes.

Renewed interest in ACE: antenatally expressed colostrum as an alternative to formula

After birth, if a baby requires additional sustenance beyond breastfeeding, for instance, if they are hypoglycaemic, formula or glucose gel is normally given. But with the advent of freezers and economically priced syringes and other collection containers, it is now feasible to collect and store any colostrum that has been expressed during pregnancy. Mothers can collect colostrum expressed in pregnancy and store it in their home freezer. If medically indicated, this colostrum can then be defrosted and given to the baby after birth, in place of formula. As a result, interest in ACE has increased in recent times. Having a supply of antenatal colostrum available is particularly relevant for newborns who are at higher risk of hypoglycaemia, including babies of mothers with diabetes mellitus (including gestational diabetes), babies with oral

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issues (cleft lip/palate), preterm babies and small or large for gestational age babies. Traditionally, these babies are given formula to help increase blood glucose levels quickly. However, if mothers have collected colostrum during pregnancy, this can be used in place of formula if required.

ACE shown to be safe

To date, the foremost research in this area is the Australian Diabetes and Antenatal Milk Expressing (DAME) trial[23]. Investigating ACE is of particular interest when considering pregnant women with diabetes, as their babies are more likely to become hypoglycaemic after birth and require treatment such as formula. This is due to a relative increase in infant insulin secretion following being in a hyperglycaemic intrauterine environment[24]. The DAME trial randomised 635 women with low-risk diabetes into either standard care or an ACE intervention with women shown how to express colostrum twice a day from 36 weeks of pregnancy. The trial demonstrated that antenatal expressing was safe: there was no difference observed between ACE or control groups for mean gestational age at birth (38.6 ± 1.03 weeks for babies in the antenatal expressing group *v.* 38.7 ± 0.98 weeks for babies in the control group, adjusted mean difference –0.05, 95% CI –0.21, 0.10) or admissions to the Neonatal Intensive Care Unit (46/317, 15% assigned to antenatal expressing *v.* 44/315, 14% assigned to standard care; adjusted relative risk 1.06, 95% CI 0.66, 1.46, adjusted for diabetes type (gestational or not), parity (first baby or not), education (degree or not), and age). The authors concluded that there is no harm in advising women with diabetes in pregnancy, at low risk of complications, to express colostrum for the last few weeks of gestation.

Since the DAME trial, studies investigating ACE have found it to be a safe practice, with no differences in weeks gestation at birth compared to controls[25–32]. In general, safety of ACE from ~36 weeks gestation has been established[28,29,33,34]. This is notably later than some previous studies, which included hand expression as early as 20 weeks gestation[16].

Although the DAME trial provided good evidence of safety in low-risk women with diabetes, researchers suggest that further studies into the introduction of ACE into high-risk groups, and earlier initiation of ACE, are necessary before it can be advised in these situations[30,35,36].

Learning about and practicing ACE

ACE education seems to be acceptable within a range of cohorts[25,30,35,37]. Most studies investigating ACE use a midwife or lactation consultant to teach pregnant women how to perform ACE. Due to staffing and funding restrictions, this is often difficult to do on a large scale. ACE instruction via a pre-recorded expert video has been previously trialled by our research team[37]. Our team has demonstrated that the use of an educational ACE video is both acceptable and efficacious in providing instruction to pregnant women, which they could then use to practice on their own and rewatch as required[37].

Barriers to performing ACE include illness, burden of existing appointments for mothers with diabetes, and lack of time[27,35,36,38]. For example, mothers with diabetes during pregnancy already have the increased burden of attending extra appointments and completing blood glucose tests throughout the day, in addition to their usual activities at work or home[36].

Overall, the experience of pregnant women learning about and practicing ACE is largely positive[39]. Qualitative research has shown that the hand expression and subsequent frozen storage of colostrum in the weeks prior to birth helps build confidence with breastfeeding[40]. Increased breastfeeding self-efficacy is a common theme that has been reported in multiple studies of ACE[41], for example, it can give women confidence in their milk supply for post-birth breastfeeding[35]. Feeling more comfortable and confident with expressing breastmilk has also been reported[27].

Although most research has been conducted in Australian and US cohorts, a small study of Scandinavian women also found that ACE was well accepted by all participants, and almost all (26/27, 96%) would recommend it to other pregnant women[34]. A mother's attitude towards breastfeeding has been shown to be a strong modifiable factor to help increase breastfeeding duration[42], suggesting ACE may help to better prepare women for breastfeeding by increasing their confidence.

However, performing ACE can be disempowering as well as empowering for women. In interviews with a subset of 10 women participating in the DAME trial, ACE was on one hand associated with feelings of achievement and control in a pregnancy that was 'controlled by diabetes'[36]. But on the other hand, some women who couldn't collect colostrum, or only collected a small amount, felt disappointed and anxious, with a sense that their bodies had not worked as they had wanted[36].

Negative feelings of performing ACE have also been reported in other studies. These included maternal discomfort with expressing, embarrassment, and concern about not being able to express colostrum[35]. Anxiety around not being able to produce colostrum through hand expression is a common theme[25,36].

Issues with use of expressed colostrum in hospital

Ideally, colostrum collected during pregnancy would be kept safely frozen at home and only brought in (frozen) to be defrosted for use during the hospital stay if medically indicated, with parents supported through that process. However, there have been reports of parents feeling disheartened by the lack of support for the use of stored colostrum within the hospital setting[30,35,36]. In these cases, parents would sometimes leave the hospital feeling like their ACE efforts had been in vain[36]. Improved hospital staff education is needed to help avoid these

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experiences that may negatively influence breastfeeding practices when the families return home[35]. Appropriate on-ward freezer and fridge storage, and the ability to keep colostrum frozen in transit, is also important to allow antenatally expressed colostrum to be safely stored and accessible.

Anecdotally, we hear from midwives that postnatal women sometimes feel inclined to use their supply of antenatal colostrum during their hospital stay, even if not medically indicated. For example, a mother may ask for the collected colostrum to be fed to her baby while she catches up on sleep. This presents a potential disruption to the normal regular feeding pattern in the early days, which could have flow on effects to milk supply. It is therefore important to encourage breastfeeding to still be established as normal in the early days after birth. Ideally, antenatal colostrum would be kept frozen at home until needed or kept frozen at hospitals, so parents could take it home if not used during the hospital stay. Breastmilk including colostrum keeps for 3 months in freezer section of refrigerator with separate door (–18°C), and 6–12 months in deep freeze/chest freezer that is not opened frequently (–20°C)[43].

Colostrum and breastmilk are also useful for other areas besides feeding. Topical application of colostrum/breastmilk has been shown to be an effective treatment for nipple damage, lesions, nappy rash and conjunctivitis[44,45]. Interestingly, bovine colostrum has even been recommended for inclusion in therapeutic protocols of cancer patients[46]. Knowing that colostrum has other useful applications may ease any pressure that mothers may feel in not wanting to waste their expressed colostrum. (The lead author has had expired frozen breastmilk dried and turned into jewellery!) Women are also eager to donate excess colostrum to milk banks, to help other babies that may need it[47] – this already exists in some hospitals and could be promoted more.

ACE and breastfeeding outcomes

ACE education has generally shown positive outcomes for mothers intending to breastfeed their infants in the short term. Increased initiation of breastfeeding during the hospital stay[25,26], and a decrease in formula use while in hospital[35,41,48] are consistently reported in studies investigating ACE. The Breastfeeding and Antepartum Breast Milk Expression (BABE) randomised control trial was a notable exception to this; this study used a breast pump for antenatal expressing rather than hand expressing and found no difference in formula use during initial hospital stay compared with no intervention[29]. One disadvantage of using a pump instead of hand expressing is that women do not practice the skill of hand expressing. This skill is useful when wanting to express a small amount of colostrum post-birth, for example, to help baby with attaching.

For longer-term breastfeeding outcomes, there is conflicting evidence as to the efficacy of using ACE. A systematic review reported an increase in breastfeeding rates for women with diabetes up to three months post-birth[39]; a separate review found studies often reported increases but these were not always statistically significant[30]. In randomised controlled trials, there is also evidence that mothers receiving an ACE intervention had similar breastfeeding rates at three and six months when compared to mothers in control groups[28,29,32]. At this stage, there is no good quality evidence to show that ACE significantly improves rates of long-term breastfeeding.

Does performing ACE affect postnatal colostrum?

If a pregnant mother is expressing colostrum in the weeks prior to birth, could this result in any detrimental changes to the colostrum once the baby is born? There is currently little known on whether extracting colostrum prior to birth results in a change to the composition of or duration of colostrum post-birth.

Waller and colleagues noted back in the 1940s that some women reported that colostrum flowed more freely after they had practised ACE for a few weeks compared to when they first started[49]. They wondered whether this could be due to a reduction in viscosity or a change in composition, and investigated both the viscosity and protein (via total nitrogen) composition of antenatal and early postnatal colostrum secretion. Samples were collected on several occasions during the last 8–10 weeks of pregnancy and daily for approximately the first-week post-birth. Samples were taken via either hand expression or pump, and sent for testing immediately or stored in a refrigerator prior to testing. Results, from 45 participants, showed a wide variation in viscosity and total nitrogen between individual mothers[49]. However, neither of these factors were systematically lower or higher as a result of performing ACE. A tendency was noted in many cases for all factors to reach their highest values at the time of birth, or shortly after. The peak in viscosity and protein content in the majority of cases was on the second or third day after birth, although sometimes as early as a few hours after delivery and sometimes as late as the fourth day. In addition, they did not find any evidence that the regular removal of antenatal colostrum shortens the period of time postnatally when colostrum is produced. However, the researchers were not able to recruit as many mothers as they were aiming for, due to a bomb destroying a large part of the hospital including their testing equipment during the war. This suggests the study could have potentially been underpowered.

Since the 1940s our knowledge of colostrum composition and the equipment available to test different aspects of composition has improved greatly. The Antenatal Colostrum Expression (ACE) Study (detailed in the following section) aims to evaluate this further.

Studies underway

The ACE Study is currently investigating the efficacy of ACE on breastfeeding outcomes in non-diabetic, low-risk, first-time mothers in Australia[50]. It will analyse data

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from three groups of participants: those randomised to in-person ACE education or pre-recorded video ACE education, and a control group who received standard antenatal care and education. Our research team is also aiming to investigate differences in colostrum composition between mothers in the ACE and control groups. ACE research in the USA is also currently being undertaken by Jill Demirci and colleagues[28] who are looking at a similar cohort of primiparas birthing parents but with a pre-pregnancy body mass index of at least 25. Recruitment for this randomised controlled trial is finished ($n = 280$) and the research team are currently finishing data collection.

Directions for future research

Many of the studies reviewed were conducted in relatively homogeneous groups of pregnant women with diabetes[32,34,36,47,48]. The majority of studies have been on cohorts from Australia and the United States, so results may not be generalisable to other populations[23,31,34,35,47,48]. Further research in more diverse population groups such as minority ethnic groups, different socio-economic groups, those giving birth to babies with congenital defects, those at risk of preterm birth, and people from the LGBTQI+ community would be beneficial to discover whether ACE would be an appropriate intervention for women and other birthing people from these groups[25,27,30,32,35,36,38,39,41].

Future research could also investigate health effects of using defrosted frozen antenatally expressed colostrum for the infant. Both the freezing and thawing process and the colostrum being expressed antenatally may potentially influence the quality of the colostrum. Further, infants are exposed to circadian cues through breastfeeding via hormones such as melatonin that transfer to milk via the mother's plasma[51]. If colostrum is frozen, how could that affect circadian rhythms in the newborn? In addition to hormones present, nutritional aspects like fat and amino acids can also differ in concentration during the daytime and at night[51]. Comparison of antenatally expressed and fresh colostrum versus formula for newborn feeding would be interesting to investigate further, in terms of gut health, immune function, allergy and longer-term health.

Conclusion

The history of ACE reflects evolving practices surrounding maternal and infant health. Many hospitals around the world including Australia, the UK, the USA and Ireland now promote the use of ACE[52–55], although some hospitals only advise it for certain groups, for example, diabetes in pregnancy, previous feeding difficulties or vulnerable babies[56–58]. As our understanding of lactation and infant nutrition continues to grow, ACE is likely to continue in popularity for its role in increasing breastfeeding confidence in pregnancy, assisting with development of hand-expressing skills, and decreasing reliance on formula used in the early days of life. Alongside this, we also need to ensure that pregnant women are well supported to help limit anxiety around a potential inability to express colostrum antenatally, and support for appropriate storage and use of antenatal colostrum during the establishment of breastfeeding.

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Author contributions

TOS conceptualised, drafted and reviewed the manuscript, CI provided summaries of modern studies and hospital practices and provided feedback on the manuscript.

Competing interests

The authors have no conflicts of interest.

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