Pediatric Nutrition
CONTINUING EDUCATION FOR CLINICIANS

COURSE TRANSCRIPT

Neonate Feeding Regimens and the Expanding Role of Lactoferrin

Overview

Human breast milk is the gold standard, providing a myriad of health benefits. Lactoferrin, which is found in high concentration in mammalian milk, is a multifunctional glycoprotein that has antimicrobial and immunomodulatory properties. Paolo Manzoni, MD, PhD, explains its critical role in protecting neonates against infection.

Historically, lactoferrin has been low in infant formula due to lower levels in bovine milk; however, advanced technology concentrated bovine lactoferrin in formula. Data show how much lactoferrin is needed, and when it is appropriate to supplement. Lactoferrin supplementation—human or bovine—appears to have measurable clinical benefits. Although inconsistencies exist among major RCTs in terms of lactoferrin efficacy, in study results, Dr. Manzoni identifies various heterogeneity as a cause.

Target Audience

This activity was developed for neonatologists, nurses, nurse practitioners, dietitians, hospital pharmacists, and other health care providers who have an interest in newborns, infants and toddlers.

Learning Objectives

At the conclusion of this activity, participants should be better able to:

- Evaluate clinical research that is expanding the understanding of the physiological and developmental properties of lactoferrin
- Develop evidence-based NICU feeding regimens with lactoferrin.

Faculty

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Neonate Feeding Regimens and the Expanding Role of Lactoferrin

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Faculty

Paolo Manzoni, MD, PhD

Speakers Bureau	Sodilac—clinical area: Lactoferrin use in infants
	Mead Johnson Nutrition—clinical area: infant nutrition

The faculty for this activity has disclosed that there will be discussion about the use of products for non-FDA approved applications.

Additional content planners

Victoria Anderson (Medical writer)

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This activity is supported by an independent educational grant from **Mead Johnson Nutrition**.

This activity is an online enduring material. It has been edited to meet requirements for online learning. Successful completion is achieved by reading and/or viewing the materials, reflecting on its implications in your practice, and completing the assessment component.

The estimated time to complete the activity is 1.0 hour.

This activity was released on June 4, 2020 and is eligible for credit through June 4, 2022.

Neonate Feeding Regimens and the Expanding Role of Lactoferrin

Obtain your CE/CME credit at:
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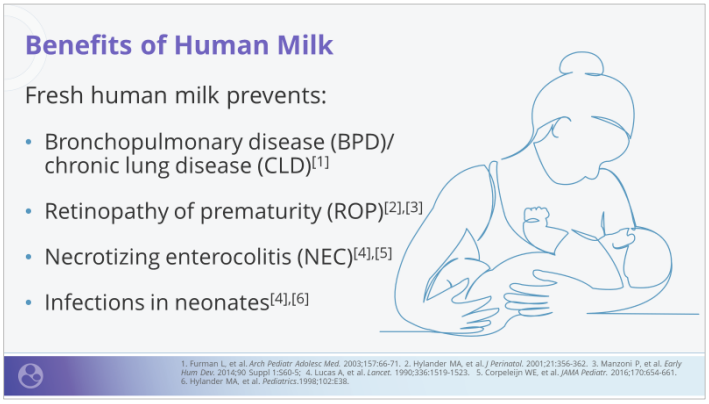
Editor's Note: This is a transcript of an audio webcast presented on May 20, 2020. It has been edited and condensed for clarity

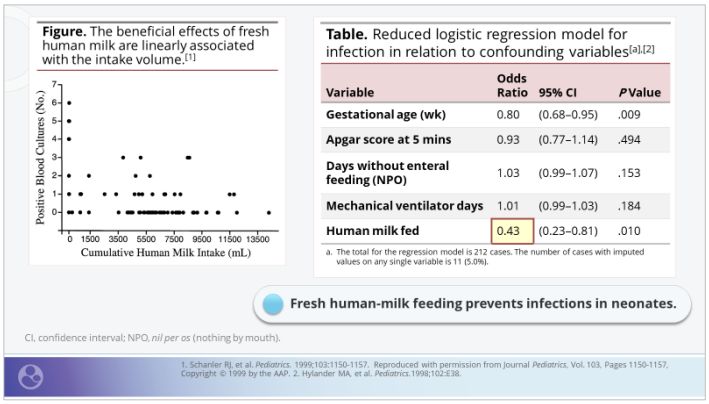
Paolo Manzoni, MD, PhD: It's my pleasure to be here today and to go through this presentation of lactoferrin with the most recent updates and with an overview of the role of lactoferrin in nutrition of preterm infants, specifically whether lactoferrin has a role, thanks to its properties, in good development of the neonatal period and of the period following birth.

The benefits of human milk are well known by everyone. Fresh human milk is reported to prevent bronchopulmonary disease (BPD), chronic lung disease, retinopathy of prematurity (ROP), necrotizing enterocolitis (NEC), and especially infections in neonates. This activity against infection is noteworthy because it is related to the intake of human milk.[1-6]



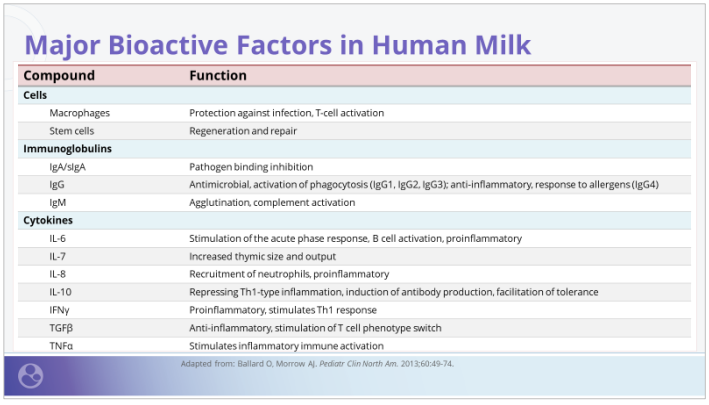
Slide 1 – Benefits of Human Milk

It has been estimated, according to a series of neonates fed with human milk, that babies need to receive at least 50 ml/kg/day of fresh human milk, and this translates into a 50%–60% reduction of the odds of developing sepsis. In this view, we know that these fascinating properties of human milk should be attributable to a number of bioactive factors that can be retrieved in human milk.



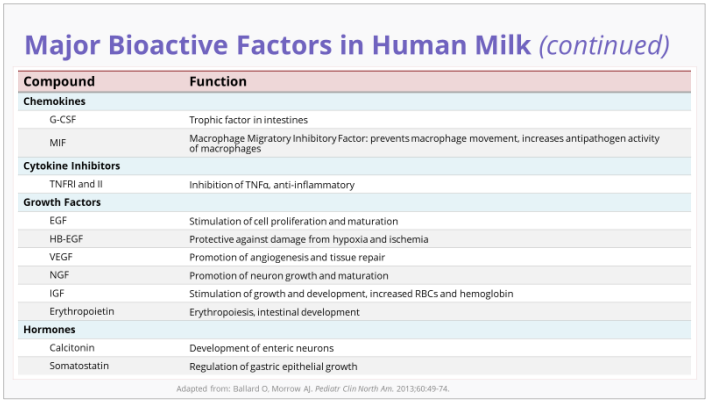
Slide 2

You see in this slide [Slide 2], and in the next couple of slides, that the list of putative actors in prevention of infection is truly long [Slides 3–5], with several actions and several modalities that, of course, cannot but be interactive between each other. Lactoferrin stands as one of the most likely important bioactive factors with specific anti-infective activity.[6,7]

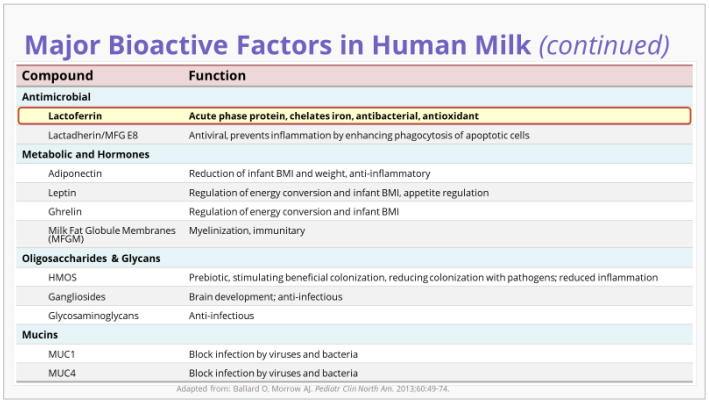


Slide 3 – Major Bioactive Factors in Human Milk

Neonate Feeding Regimens and the Expanding Role of Lactoferrin

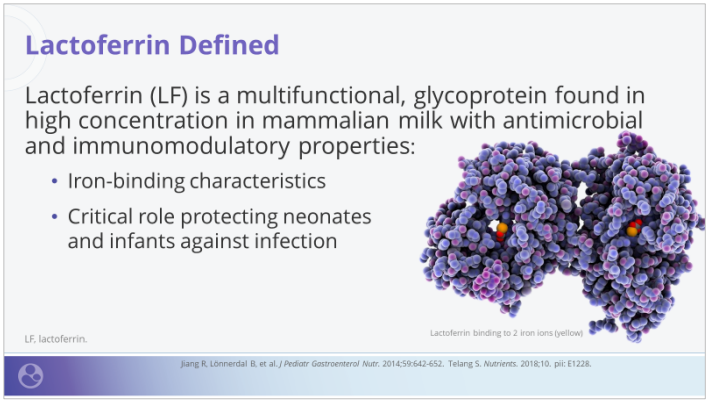


Slide 4 – Major Bioactive Factors in Human Milk (continued)



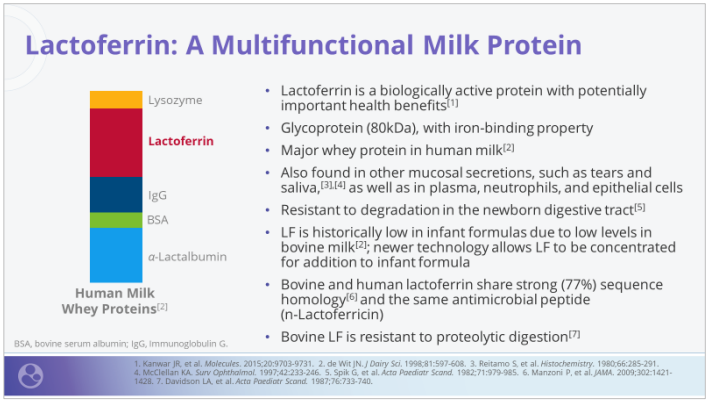
Slide 5 – Major Bioactive Factors in Human Milk (continued)

And this is true for lactoferrin, also, thanks to its iron-binding characteristics, which we'll be elucidating later on. As a matter of fact, lactoferrin is multifunctional, and it's very widely represented in human milk because, just as in mammal milk, it's a considerable part for all the human milk whey-proteins portfolio. It's a glycoprotein and can also be found in other secretions, such as saliva, plasma, and neutrophils [Slide 6].[8,9]



Slide 6 – Lactoferrin Defined

Historically, lactoferrin is very low in formula milk because lactoferrin in cow's milk is not very concentrated, with respect to colostrum in human milk. It's very important, however, [to note] that bovine and human lactoferrin share a very strong homology in biochemical structure. Most of all, they have the same antimicrobial peptide called N-lactoferricin. It's an 11 amino-acidic peptide placed on the N-terminal side of the protein.[10-16]



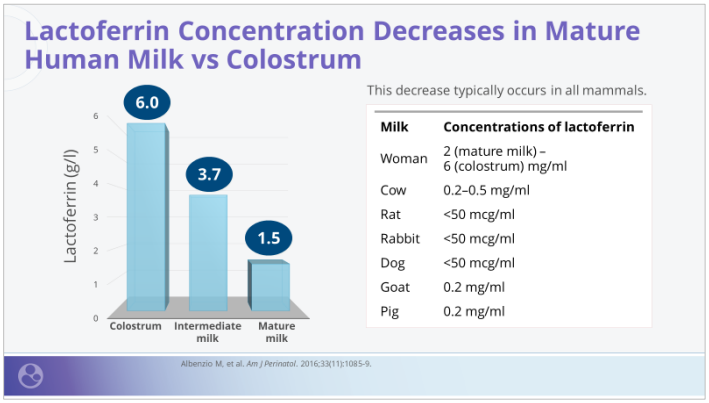
Slide 7 – Lactoferrin: A Multifunctional Milk Protein

Critical role in immune response

Lactoferrin, as I was alluding to, is not only a milk protein, because it's a part of a more complex antimicrobial protein network of inflammatory markers that have a critical role in immune response during infections. In fact, lactoferrin is released by neutrophils, by mucosal secretion. It's highly represented in the ocular liquid during

ophthalmitis. It's highly represented in saliva. It's highly represented in all places where an inflammatory response occurs.[17]

It's very important to underline the typical pattern, the typical trend of the decreasing concentration of lactoferrin during different stages of lactation. In colostrum, lactoferrin is abundant with the concentration estimated around 6 g per liter. But this concentration decreases to 1.5 g/l in mature milk. And this decrease occurs typically in all mammals.[18]



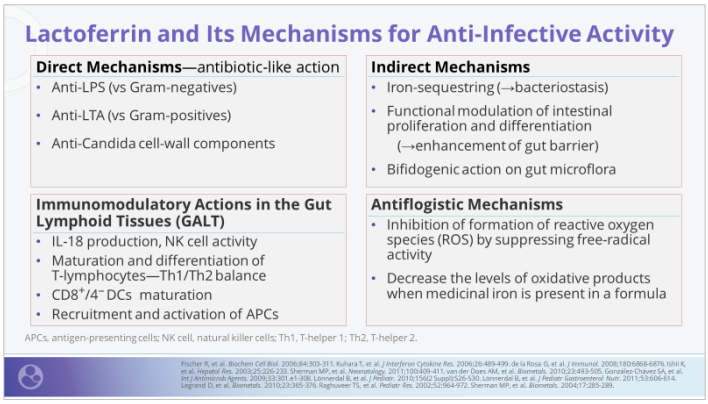
Slide 8 – Lactoferrin Concentration Decreases in Mature Human Milk vs Colostrum

That means the action and the role of lactoferrin is even more critical in the periods in which all human beings—and I would dare to say, all mammalian beings—receive colostrum.

Anti-infective activity

This is a representation of all the different actions exerted by lactoferrin in terms of anti-infective activity [Slide 9]. There are direct mechanisms of action that can be defined antibiotic-like by targeting different epitopes of the pathogens: [Lipopolysaccharide] LPS with gram-negatives, [Lipoteichoic acid] LTA with gram-positives, as an example. But there are also indirect mechanisms; one of them would be in iron-sequestering ability, ultimately prompting to bacteriostasis.

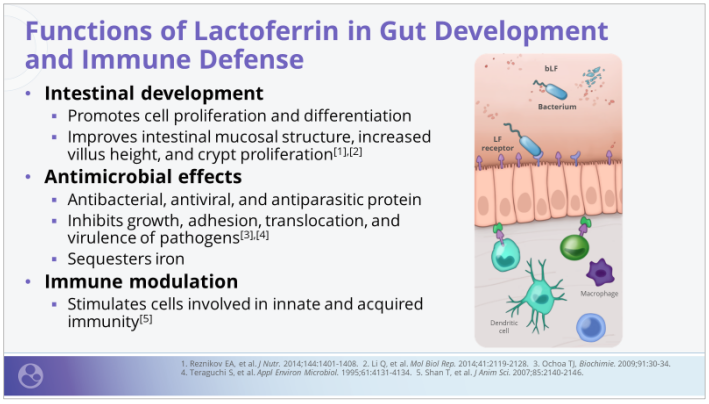
An indirect mechanism—and probably a very important one—is the ability to modulate the function and the development of the intestinal enterocyte by mixing actions of proliferation and differentiation, thus enhancing the gut barrier in a period in which the gut is terribly leaky. An indirect mechanism, [also includes] the ability to promote a good bifidogenic microflora in the gut.



Slide 9 – Lactoferrin and Its Mechanisms for Anti-Infective Activity

Promoting intestinal development

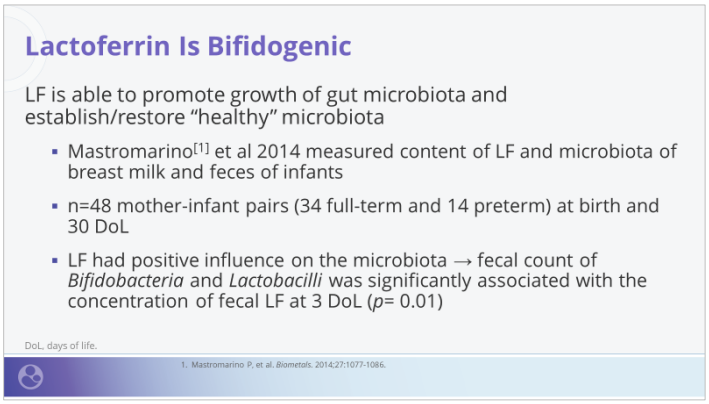
We will see later on, but I want to focus once more on the ability of lactoferrin to promote intestinal development. In doing so, ultimately reaching the ability to exert true antimicrobial effects, because enterocyte developing in a correct way and proliferating rapidly soon after birth are effective in promoting the establishment of a gut barrier that prevents pathogens from translocation from the gut to the bloodstream.[19-23]



Slide 10 – Functions of Lactoferrin in Gut Development and Immune Defense

Bifidogenic factor

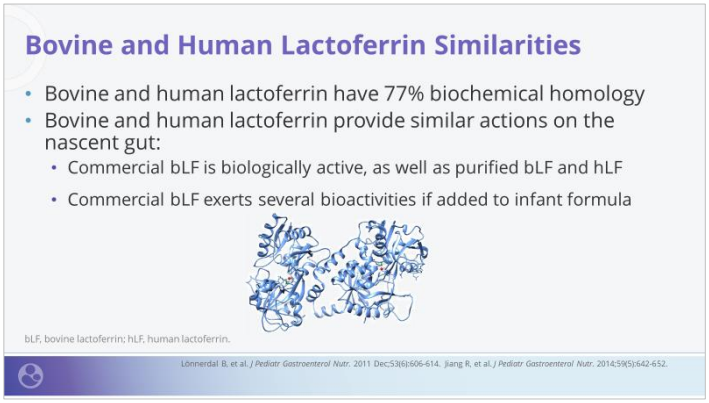
I was telling you that lactoferrin is bifidogenic. This is data that we obtained in Italy,[24] thanks to the group in Rome [Slide 11]. This group was able to measure content of lactoferrin and characteristics of microbiota in breast milk and in stools of infants who had been breastfed. By studying 48 mother-infant pairs at birth and after 30 days of life, investigators came to the conclusion, and to the evidence, that the fecal count of *Bifidobacteria* and *Lactobacilli* were significantly associated with the concentration of fecal lactoferrin after birth. The concentration of fecal lactoferrin was significantly associated with the concentration of milk lactoferrin in the human milk of the mothers. So, the [correlation] towards human milk lactoferrin and good microbiota has been demonstrated.



Slide 11 – Lactoferrin Is Bifidogenic

Human and bovine lactoferrin similarities

It is important to know that human and bovine lactoferrin are very similar in biochemical structure, just as I was telling you. Also, in several experiments, it has been tested that bovine and human lactoferrin actually have the same actions on the nascent gut. In particular, both of them are fully able to promote the proliferation and differentiation of the enterocyte, just as I was telling you. Commercial bovine lactoferrin might even be (in several experiments) a little more active than human lactoferrin on enterocyte *in vitro*. Therefore, we suspect, and we presume that once added to infant formula, bovine lactoferrin may actually develop the same actions as in human milk.[8,25]

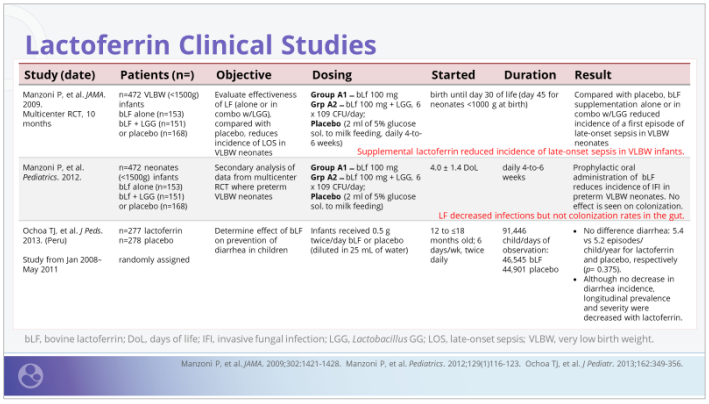


Slide 12 – Bovine and Human Lactoferrin Similarities

Lactoferrin clinical trials

We go now to discuss clinical studies. This has been a matter and a target of a number of studies conducted in the last 10 years. Some 15 randomized clinical trials, both multicenter and single center, exploring the ability of lactoferrin to promote the prevention of sepsis, to prevent necrotizing enterocolitis, and ultimately to enhance the well-being of a neonate and infant over the first weeks of life.

Neonate Feeding Regimens and the Expanding Role of Lactoferrin



Lactoferrin Clinical Studies

Study (date)	Patients (n=)	Objective	Dosing	Started	Duration	Result
Manzoni P, et al. *JAMA*. 2009. Multicenter RCT, 10 months	n=472 VLBW (<1500g) infants bLF alone (n=153) bLF + LGG (n=151) or placebo (n=168)	Evaluate effectiveness of LF (alone or in combo w/LGG), compared with placebo, reduces incidence of LOS in VLBW neonates	**Group A1 –** bLF 100 mg **Grp A2 –** bLF 100 mg + LGG, 6 x 109 CFU/day; **Placebo** (2 ml of 5% glucose sol. to milk feeding, daily 4-to-6 weeks)	birth until day 30 of life (day 45 for neonates <1000 g at birth)		Compared with placebo, bLF supplementation alone or in combo w/LGG reduced incidence of a first episode of late-onset sepsis in VLBW neonates Supplemental lactoferrin reduced incidence of late-onset sepsis in VLBW infants.
Manzoni P, et al. *Pediatrics*. 2012.	n=472 neonates (<1500g) infants bLF alone (n=153) bLF + LGG (n=151) or placebo (n=168)	Secondary analysis of data from multicenter RCT where preterm VLBW neonates	**Group A1 –** bLF 100 mg **Grp A2 –** bLF 100 mg + LGG, 6 x 109 CFU/day; **Placebo** (2 ml of 5% glucose sol. to milk feeding)	4.0 ± 1.4 DoL	daily 4-to-6 weeks	Prophylactic oral administration of bLF reduces incidence of IFI in preterm VLBW neonates. No effect is seen on colonization. LF decreased infections but not colonization rates in the gut.
Ochoa TJ, et al. *J Peds*. 2013. (Peru) Study from Jan 2008–May 2011	n=277 lactoferrin n=278 placebo randomly assigned	Determine effect of bLF on prevention of diarrhea in children	Infants received 0.5 g twice/day bLF or placebo (diluted in 25 mL of water)	12 to ≤18 months old; 6 days/wk, twice daily	91,446 child/days of observation: 46,545 bLF 44,901 placebo	• No difference diarrhea: 5.4 vs 5.2 episodes/ child/year for lactoferrin and placebo, respectively (p= 0.375). • Although no decrease in diarrhea incidence, longitudinal prevalence and severity were decreased with lactoferrin.

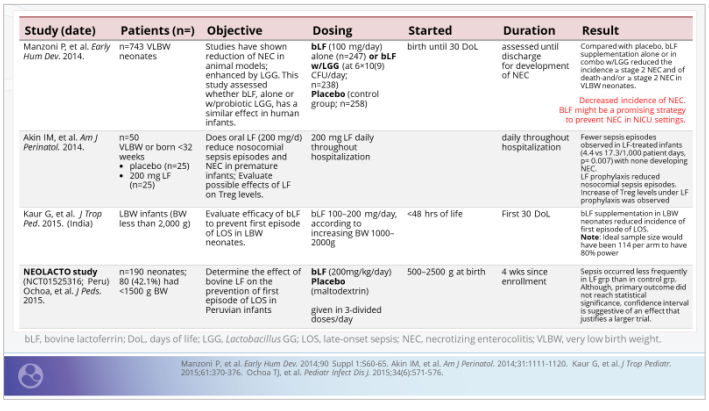
bLF, bovine lactoferrin; DoL, days of life; IFI, invasive fungal infection; LGG, *Lactobacillus* GG; LOS, late-onset sepsis; VLBW, very low birth weight.

Manzoni P, et al. *JAMA*. 2009;302:1421-1428. Manzoni P, et al. *Pediatrics*. 2012;129(1)116-123. Ochoa TJ, et al. *J Pediatr*. 2013;162:349-356.

Slide 13 – Lactoferrin Clinical Studies

The first study was conducted by our group. It was published in *JAMA*.[15] Probably many of you know it from 2009 [Slide 13]. It was the first demonstration that bovine lactoferrin, when supplemented to the regular feeds, was able to reduce the incidence of late-onset sepsis in very low-birth-weight infants.

After this study, many more [have been added]…[Slide 24] with most of them providing results similar to what we could provide. Groups in Peru, groups in Turkey, groups in India, groups in Canada, explored different dosing regimens, different categories of premature infants.[26-30] Most of them, up to last year, were able to show similar ability of lactoferrin to promote well-being of the infants and to prevent late-onset sepsis.



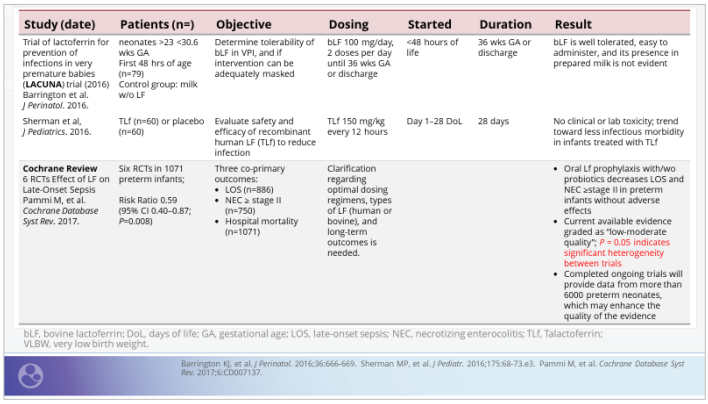
Study (date)	Patients (n=)	Objective	Dosing	Started	Duration	Result
Manzoni P, et al. *Early Hum Dev*. 2014.	n=743 VLBW neonates	Studies have shown reduction of NEC in animal models; enhanced by LGG. This study assessed whether bLF, alone or w/probiotic LGG, has a similar effect in human infants.	**bLF** (100 mg/day) alone (n=247) **or bLF w/LGG** (at 6×10(9) CFU/day; n=238) **Placebo** (control group; n=258)	birth until 30 DoL	assessed until discharge for development of NEC	Compared with placebo, bLF supplementation alone or in combo w/LGG reduced the incidence ≥ stage 2 NEC and of death and/or ≥ stage 2 NEC in VLBW neonates. Decreased incidence of NEC. BLF might be a promising strategy to prevent NEC in NICU settings.
Akin IM, et al. *Am J Perinatol*. 2014.	n=50 VLBW or born <32 weeks • placebo (n=25) • 200 mg LF (n=25)	Does oral LF (200 mg/d) reduce nosocomial sepsis episodes and NEC in premature infants; Evaluate possible effects of LF on Treg levels.	200 mg LF daily throughout hospitalization		daily throughout hospitalization	Fewer sepsis episodes observed in LF-treated infants (4.4 vs 17.3/1,000 patient days, p=0.007) with none developing NEC. LF prophylaxis reduced nosocomial sepsis episodes. Increase of Treg levels under LF prophylaxis was observed
Kaur G, et al. *J Trop Ped*. 2015. (India)	LBW infants (BW less than 2,000 g)	Evaluate efficacy of bLF to prevent first episode of LOS in LBW neonates.	bLF 100–200 mg/day, according to increasing BW 1000–2000g	<48 hrs of life	First 30 DoL	bLF supplementation in LBW neonates reduced incidence of first episode of LOS. **Note**: Ideal sample size would have been 114 per arm to have 80% power
NEOLACTO study (NCT01525316; Peru) Ochoa, et al. *J Peds*. 2015.	n=190 neonates; 80 (42.1%) had <1500 g BW	Determine the effect of bovine LF on the prevention of first episode of LOS in Peruvian infants	**bLF** (200mg/kg/day) **Placebo** (maltodextrin) given in 3-divided doses/day	500–2500 g at birth	4 wks since enrollment	Sepsis occurred less frequently in LF grp than in control grp. Although, primary outcome did not reach statistical significance, confidence interval is suggestive of an effect that justifies a larger trial.

bLF, bovine lactoferrin; DoL, days of life; LGG, *Lactobacillus* GG; LOS, late-onset sepsis; NEC, necrotizing enterocolitis; VLBW, very low birth weight.

Manzoni P, et al. *Early Hum Dev*. 2014;90 Suppl 1:S60-65. Akin IM, et al. *Am J Perinatol*. 2014;31:1111-1120. Kaur G, et al. *J Trop Pediatr*. 2015;61:370-376. Ochoa TJ, et al. *Pediatr Infect Dis J*. 2015;34(6):571-576.

Slide 14

The last published Cochrane review, in 2017,[31] included 6 randomized clinical trials, with more than 1000 preterm infants, and was able to establish that there was a 41% reduction attributed to lactoferrin in late-onset sepsis [Slide 15]. However, the evidence was graded as low-to-moderate quality with significant heterogeneity between trials. There is clearly room for additional trials warranted in order to confirm or discard the ability of lactoferrin to prevent sepsis and also NEC.



Study (date)	Patients (n=)	Objective	Dosing	Started	Duration	Result
Trial of lactoferrin for prevention of infections in very premature babies (**LACUNA**) trial (2016) Barrington et al. *J Perinatol*. 2016.	neonates >23 <30.6 wks GA First 48 hrs of age (n=79) Control group: milk w/o LF	Determine tolerability of bLF in VPI, and if intervention can be adequately masked	bLF 100 mg/day, 2 doses per day until 36 wks GA or discharge	<48 hours of life	36 wks GA or discharge	bLF is well tolerated, easy to administer, and its presence in prepared milk is not evident
Sherman et al, *J Pediatrics*. 2016.	TLf (n=60) or placebo (n=60)	Evaluate safety and efficacy of recombinant human LF (TLf) to reduce infection	TLf 150 mg/kg every 12 hours	Day 1–28 DoL	28 days	No clinical or lab toxicity; trend toward less infectious morbidity in infants treated with TLf
Cochrane Review 6 RCTs Effect of LF on Late-Onset Sepsis Pammi M, et al. *Cochrane Database Syst Rev*. 2017.	Six RCTs in 1071 preterm infants; Risk Ratio 0.59 (95% CI 0.40–0.87; P=0.008)	Three co-primary outcomes: • LOS (n=886) • NEC ≥ stage II (n=750) • Hospital mortality (n=1071)	Clarification regarding optimal dosing regimens, types of LF (human or bovine), and long-term outcomes is needed.			• Oral Lf prophylaxis with/wo probiotics decreases LOS and NEC ≥stage II in preterm infants without adverse effects • Current available evidence graded as "low-moderate quality"; P = 0.05 indicates significant heterogeneity between trials • Completed ongoing trials will provide data from more than 6000 preterm neonates, which may enhance the quality of the evidence

bLF, bovine lactoferrin; DoL, days of life; GA, gestational age; LOS, late-onset sepsis; NEC, necrotizing enterocolitis; TLf, Talactoferrin; VLBW, very low birth weight.

Barrington KJ, et al. *J Perinatol*. 2016;36:666-669. Sherman MP, et al. *J Pediatr*. 2016;175:68-73.e3. Pammi M, et al. *Cochrane Database Syst Rev*. 2017;6:CD007137.

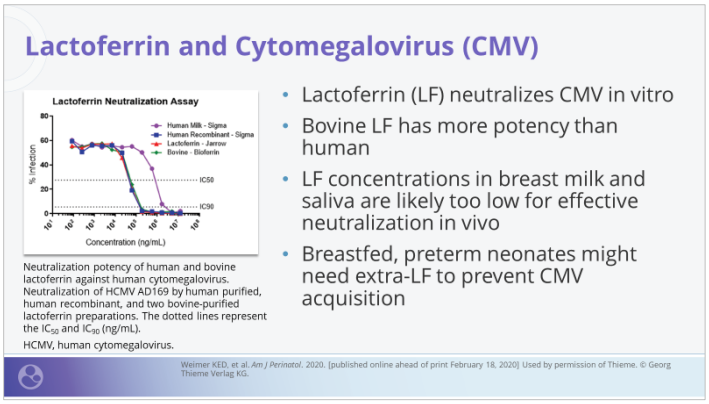
Slide 15

Lactoferrin tackling cytomegalovirus

In the meanwhile, several studies have been experimentally assessing the ability of lactoferrin to tackle cytomegalovirus (CMV) [Slide 16]. You all know that cytomegalovirus in human milk is of concern, especially in premature infants.

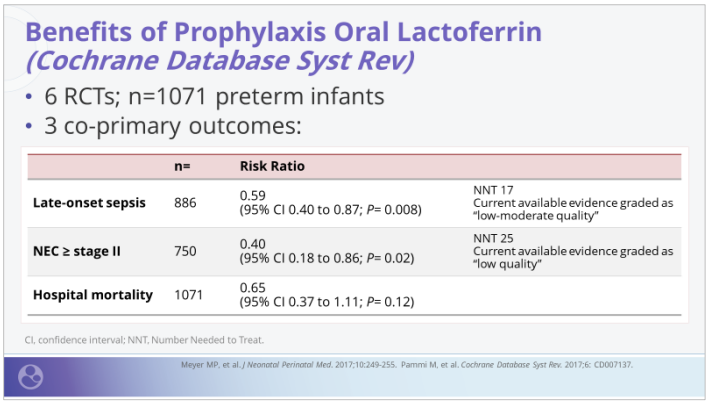
This group, led by David Kaufman in Virginia,[32] has performed several assays assessing the ability of different types of lactoferrin, compared with cytomegalovirus, to inhibit the growth and proliferation of cytomegalovirus. And the findings are very interesting because lactoferrin actually neutralizes cytomegalovirus *in vitro*. And bovine lactoferrin is even more potent than human. What's disappointing is that the naturally occurring concentrations of lactoferrin in breast milk and saliva are likely too low for effective neutralization *in vivo*. And this explains why, even in breastfeeding, the concern of transmitting cytomegalovirus is still there. Therefore, these findings advocate for assessing the opportunity to give extra lactoferrin to

preterm neonates who are breastfed, when there is a risk to transmit the cytomegalovirus.



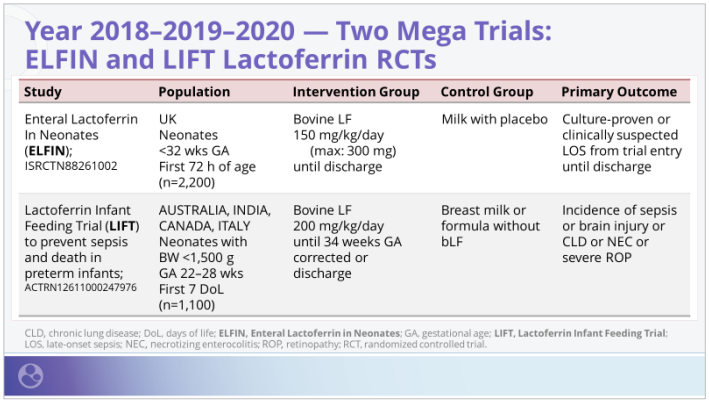
Slide 16 – Lactoferrin and Cytomegalovirus (CMV)

Getting back to the Cochrane review, I was telling you that 41% [reduction in LOS] was seen, but this was clearly in need, and pending the results of 2 major trials conducted in the last 2 years—one in the UK and the other in Australia: the ELFIN trial and the LIFT trial [Slide 18].



Slide 17 – Benefits of Prophylaxis Oral Lactoferrin

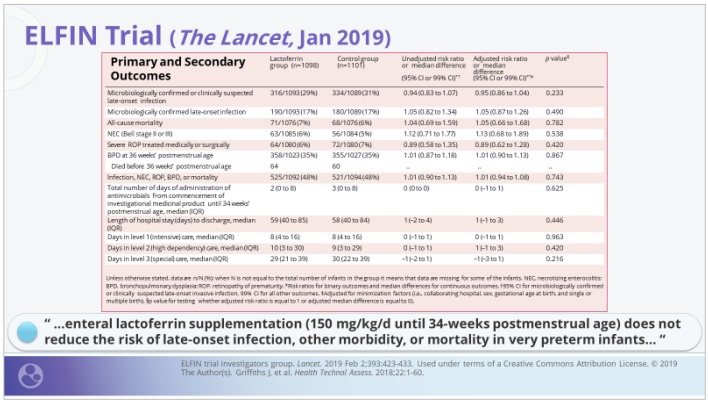
Both of them have been published, and I will go through the results in order to show what is happening now, and how the results of these very recent large trials can be reconciled with existing literature.



Slide 18 – Year 2018-2019-2020—Two Mega Trials: ELFIN and LIFT Lactoferrin RCTs

ELFIN trial

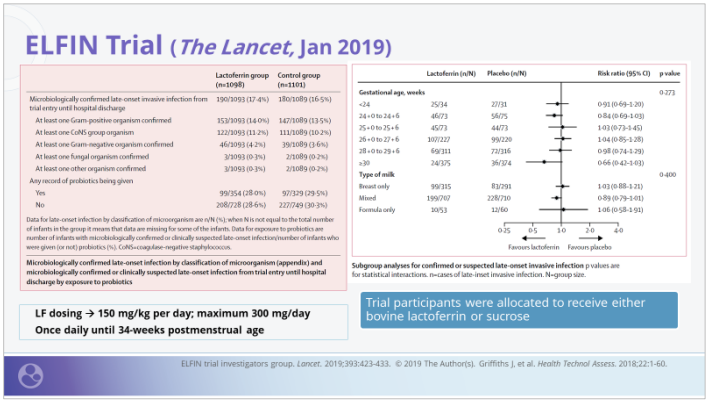
The ELFIN trial was published in the *Lancet* one year ago, and it was absolutely disappointing because the goal investigators had was not achieved.[33] Lactoferrin supplementation, 150 mg/kg/day until 34 weeks of post-menstrual age was not able to prevent or reduce the risk of late-onset infection. The reduction was only 6%, [which is] not significant.



Slide 19 – ELFIN Trial

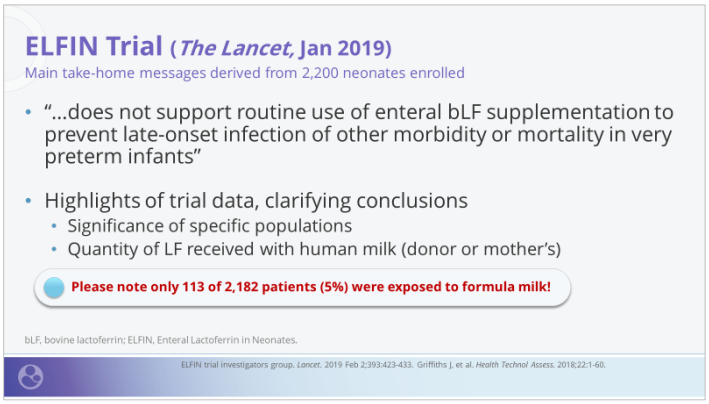
This was true, more or less, in all categories of preterm infants, and in all feeding types of the infants. However, please consider that there were different conditions in this trial that might explain these disappointing results.

Neonate Feeding Regimens and the Expanding Role of Lactoferrin



Slide 20 – ELFIN Trial

In any case, the ELFIN trial has a take-home message that is clearly a pre-final word against lactoferrin. Lactoferrin in this trial was not able to reduce late-onset sepsis, and therefore, it's not recommended as supplementation.[34]

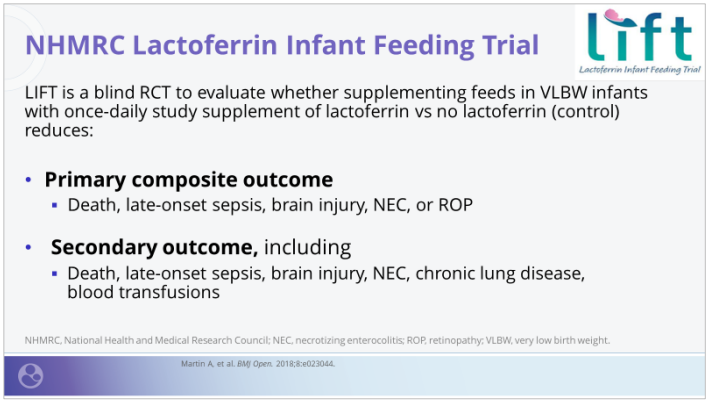


Slide 21 – ELFIN Trial

LIFT trial

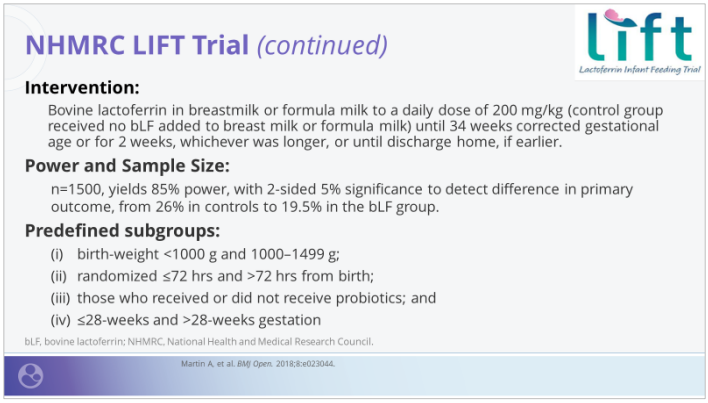
The LIFT trial was conducted during the same years and was published just a few days ago in the *Lancet Child & Adolescent Health*.[35] I will go through the results, and you will see there is room for further consideration.

Differently from other trials, the LIFT was targeting a composite outcome, which was the occurrence of death, and/or late-onset sepsis, and/or brain injury, and/or NEC, and/or ROP. So, the ultimate goal of this trial was to see whether lactoferrin improves the general health of the preterm infants.



Slide 22 – NHMRC Lactoferrin Infant Feeding Trial

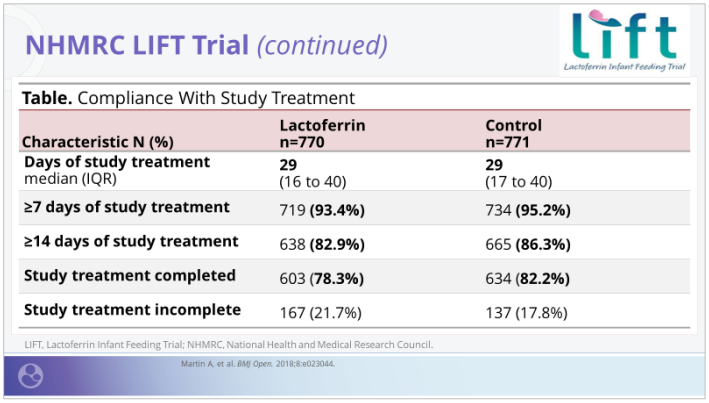
This trial recruited infants less than 1500 g; they were allocated to lactoferrin or placebo; lactoferrin dose was 200 mg/kg/day [Slide 23]. Feeds with lactoferrin were commenced up to 7 days of life. These are the characteristics of compliance, when we started treatment.



Slide 23 – NHMRC LIFT Trial (continued)

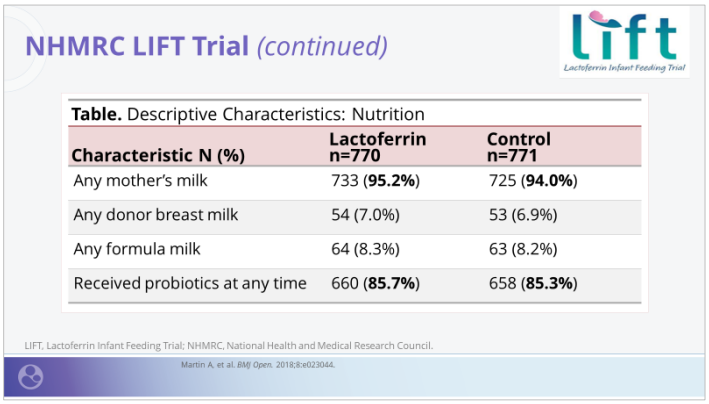
As you see [Slide 24], most infants—almost 80% of the infants—completed the study treatment. So, the results are reliable, and we have a very preliminary piece of it...very interesting information here.

The proportion of infants fed with mother's milk was 95% in both investigational groups. In addition, those who received probiotics at any time during the study were 85%. So, the vast majority received compounds, such as human milk or probiotics, which can interfere with the prevention of sepsis—clearly can prevent sepsis.



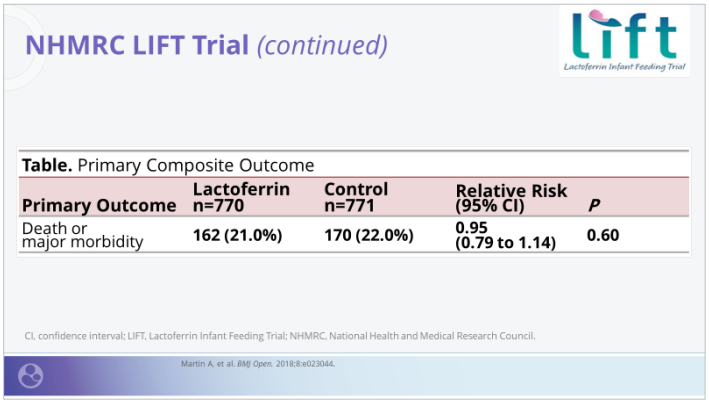
Slide 24 – NHMRC LIFT Trial (continued)

Please note that the exclusively formula milk-fed infants were only 8%, so, really few.



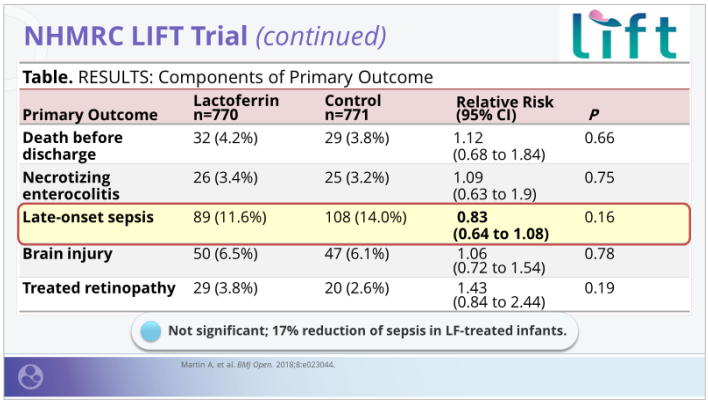
Slide 25 – NHMRC LIFT Trial (continued)

As I was telling you, the primary outcome was not met. There was a reduction by 5%, which is absolutely negligible.



Slide 26 – NHMRC LIFT Trial (continued)

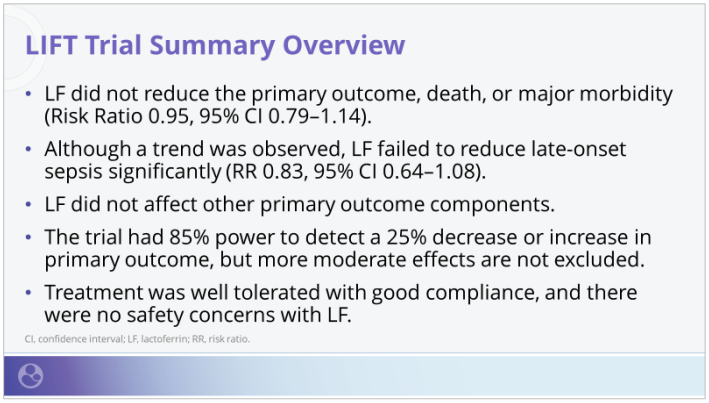
When we cluster the analysis for the different compounds of the composite outcome [Slide 27], we see that late-onset sepsis was reduced by 17%, from 14% to 11.6%. It's not significant, but there is a solid trend towards reduction, which is different from all the other outcomes that were not affected by lactoferrin.



Slide 27 – NHMRC LIFT Trial (continued)

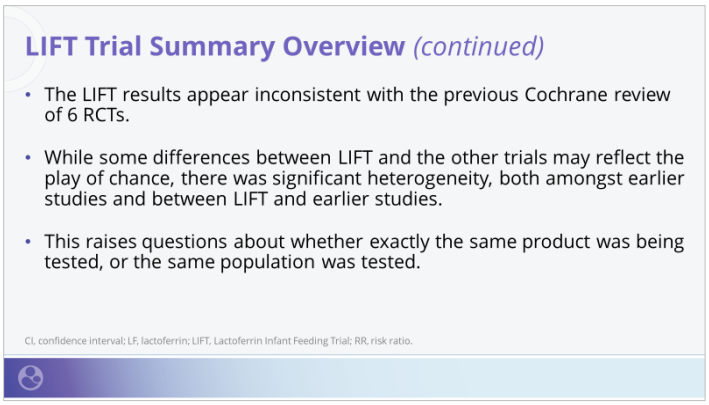
This may make sense because, as I was showing you in the first part of my talk, the activities of lactoferrin are mainly towards infections, and mainly based on several actions that target pathogens, by targeting them directly or by promoting a new modulation. So, it's not surprising that brain injury or retinopathy could not be affected by lactoferrin. But in my opinion, **it's still important that the 17% reduction in sepsis occurs.**

Well, anyway, this trial was not meeting the primary outcome. The trend in reduction of sepsis is still not significant. The power of the trial was enough to detect a 25% decrease or increase in primary outcome; however, a more moderate effect cannot be excluded. What we can say is that the treatment was absolutely well-tolerated, and this occurred also in the ELFIN trial. So, safety concerns are not at all applicable with lactoferrin, based on the evidence.



Slide 28 – LIFT Trial Summary Overview

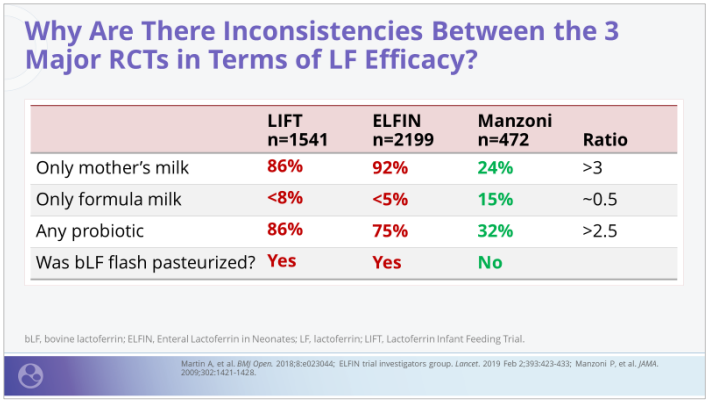
The LIFT results appear inconsistent with the Cochrane review and with the ELFIN [trial]. Maybe with the ELFIN even more, but both of them are not confirming the ability of lactoferrin to prevent sepsis. **This raises the question about whether exactly the same product has been tested in the different trials or the same population has been tested in the different trials.** We'll go through these 2 pending questions in the next slide [Slide 29].



Slide 29 – LIFT Trial Summary Overview (continued)

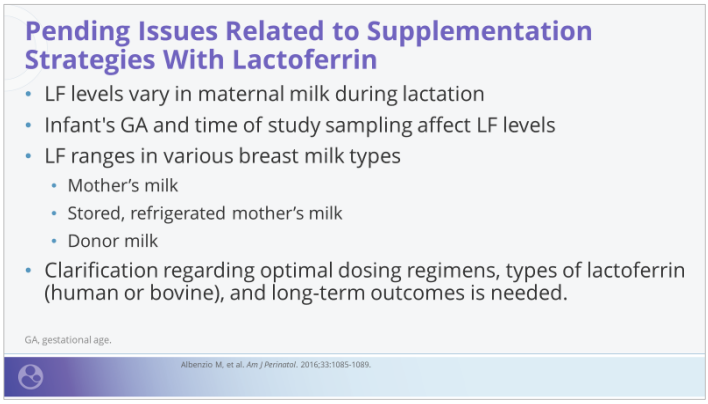
Trial inconsistencies

My first very provoking slide is this one [Slide 30]. In the different trials that have opposite results—stop lactoferrin in red, green-light to lactoferrin in green—you see that only mother's milk was received by 90% in LIFT and ELFIN, compared with 24% only in the original trial in Italy.[15,33,35]



Slide 30 – Why Are There Inconsistencies Between the 3 Major RCTs in Terms of LF Efficacy?

Only formula milk, vice versa was received by 15% in the original trial vs 5% to 8% in the 2 recent trials. Probiotic exposure was 80%, or something like this, in the LIFT and ELFIN, whereas only 32% of our kids in the original trial received probiotics. And finally, bovine lactoferrin was flash pasteurized in the 2 recent trials owing to safety reasons—but was not flash pasteurized in ours.



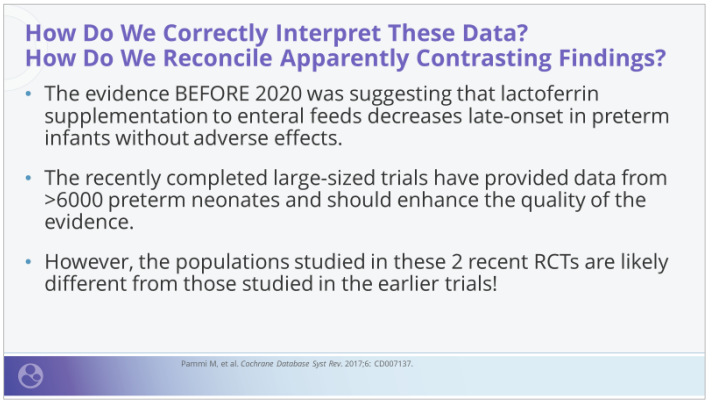
Slide 31 – Pending Issues Related to Supplementation Strategies With Lactoferrin

I think that, and I suggest for your consideration, that these 4 main differences can actually impact why the results are so strikingly different.

Please remember the **lactoferrin levels vary in maternal milk during lactation**. Please remember that these levels are varying not only in maternal milk but also when maternal milk is stored or refrigerated, or even more, if it is pasteurized as

donor milk.[18] It's clearly a matter of clarifying which lactoferrin we are using and clarifying which regimens we need to use.

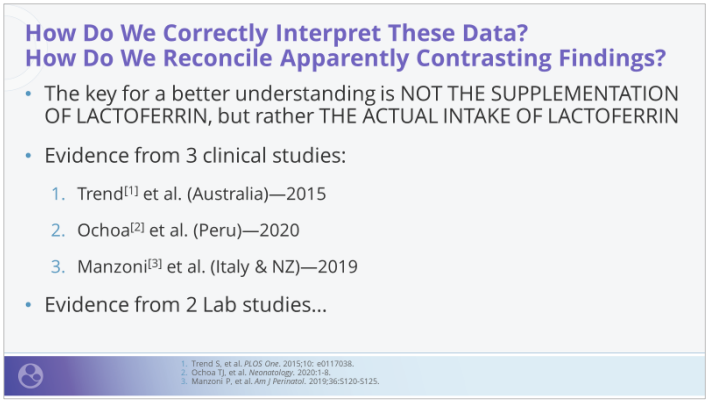
If the evidence before 2020 was suggesting that lactoferrin is effective, these recent results, based on the differences in the population that have been studied [Slide 32], might suggest that further studies are needed to understand not only whether lactoferrin is effective in preventing sepsis, but ultimately **what is the actual intake of lactoferrin providing a beneficial effect**.[31]



Slide 32 – How Do We Correctly Interpret These Data? How Do We Reconcile Apparently Contrasting Findings?

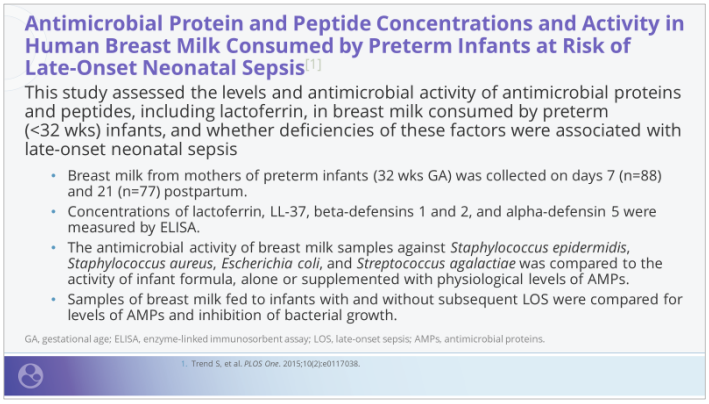
Significance of lactoferrin intake

It is possible that the issue here is not supplementation of lactoferrin simply, but it is rather how much lactoferrin is this kid getting from human milk or externally. I will guide you through these considerations, thanks to a number of studies that have been published in the last years, most clinical and *in vitro*.



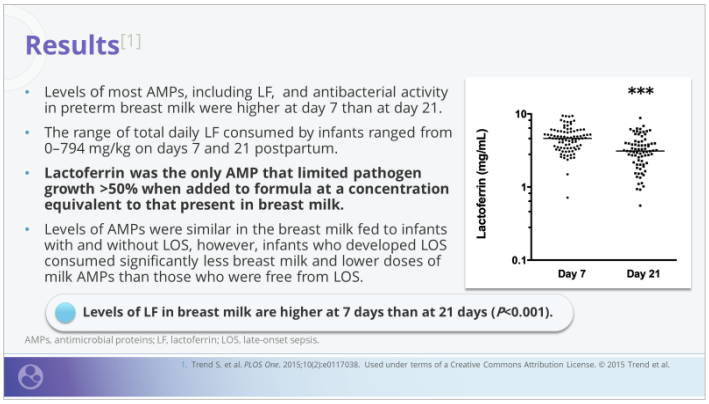
Slide 33 – How Do We Correctly Interpret These Data? How Do We Reconcile Apparently Contrasting Findings?

This one is very important. It is from a group in Australia.[36] Five years ago, they assessed the concentration of lactoferrin and the outcomes of preterm infants in a number of mothers' and infants' diet. They noted, and they demonstrated that lactoferrin was the only antimicrobial peptide that limited pathogen growth more than 50% when added to formula at a concentration equivalent to that present in breast milk. But more importantly, the addition of lactoferrin to formula milk was able to inhibit growth of all pathogens, and the effect was dose dependent. Meaning that **if you want to have an impact on pathogens, you should really care about the amount, about the intake of lactoferrin**.



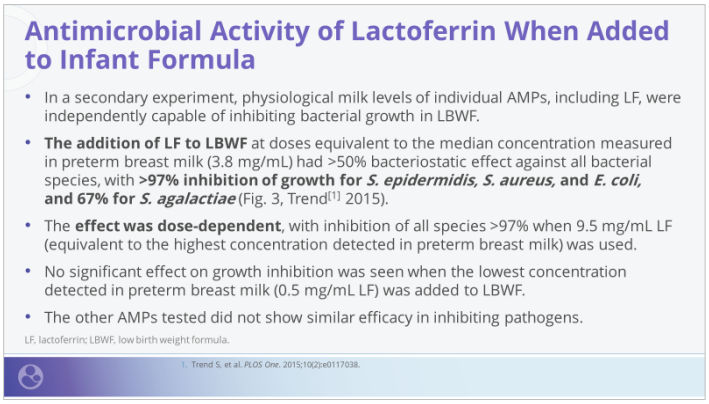
Slide 34 – Antimicrobial Protein and Peptide Concentrations and Activity in Human Breast Milk Consumed by Preterm Infants at Risk of Late-Onset Neonatal Sepsis

And the final proof of this comes from the assessment of the clinical findings from all infants in these studies. Those babies who had a late-onset sepsis episode during the course of their stay in the NICU had actually consumed and received lower intakes of lactoferrin both on day 7 of life and on day 21 [Slide 35].

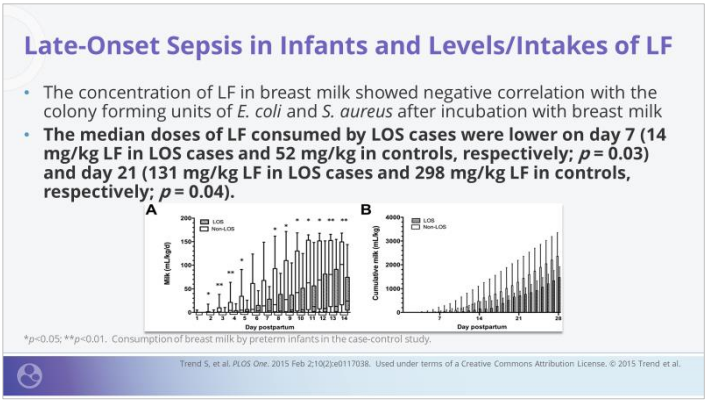


Slide 35 – Results

Please note that the lactoferrin received in a septic infant was one-fourth or one-third less than the lactoferrin received by those babies who did not develop sepsis.

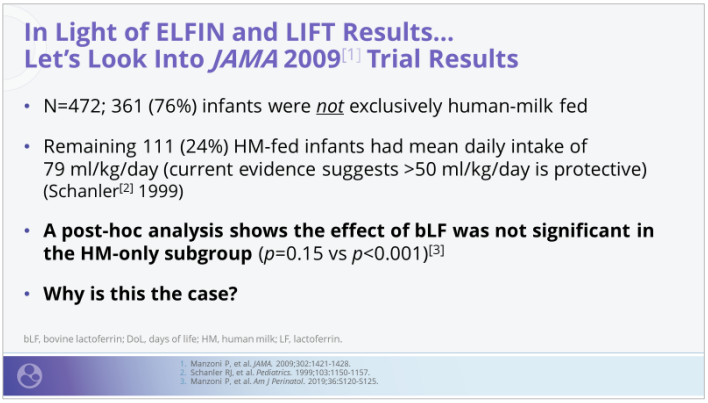


Slide 36 – Antimicrobial Activity of Lactoferrin When Added to Infant Formula



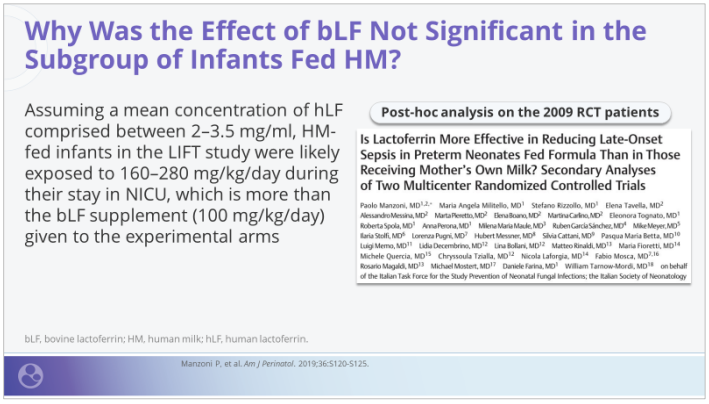
Slide 37 – Late-Onset Sepsis in Infants and Levels/Intakes of LF

The same finding was retrieved by our group when we received a secondary analysis from the data of our original trial [Slide 38]. With the post-hoc study, we showed that the effect of lactoferrin was not significant in those babies who had received only human milk.[7,15,37]



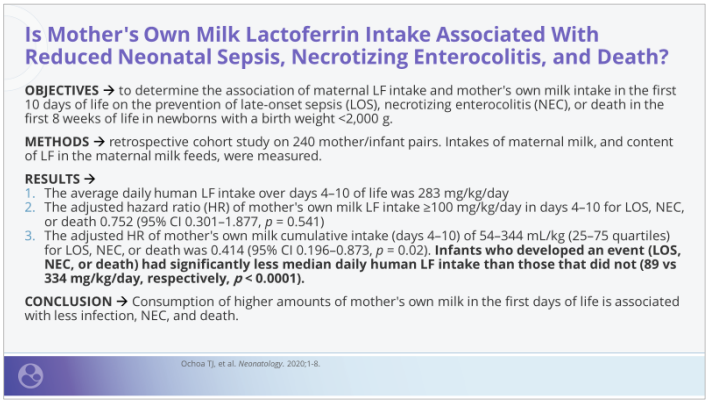
Slide 38 – In Light of ELFIN and LIFT Results... Let's Look Into JAMA 2009 Trial Results

Not only were we able to show that the exposure of human milk-fed infants in our trial was...the exposure to lactoferrin was seen in ranges spanning between 160 to 280 mg/kg/day [Slide 39]. This means that if we give 100 mg of lactoferrin a day to a baby who is already receiving 200 or more mg, maybe this is not effective because the effect is already there. It's completely different to give 100 mg of lactoferrin to a baby who is not receiving anything because he's getting formula milk.[37]



Slide 39 – Why Was the Effect of bLF Not Significant in the Subgroup of Infants Fed HM?

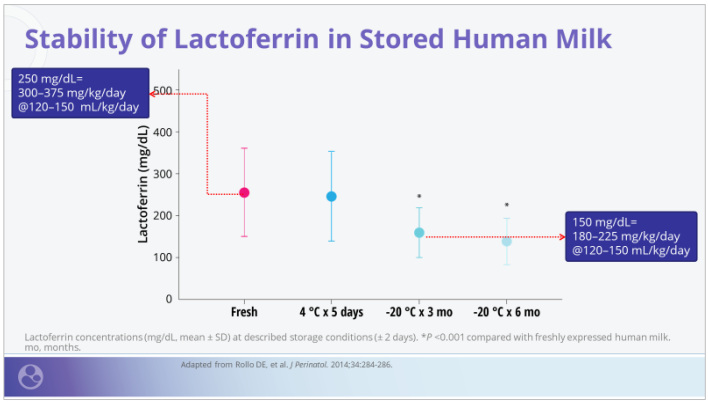
The same findings have been found recently by Theresa Ochoa in Peru [Slide 40].[38] Her group again, and once more, conducted a retrospective study assessing which was the mother-milk cumulative intake in the first weeks of life in babies developing or not developing sepsis, and drew the conclusion that the daily human lactoferrin intake in babies not featuring sepsis was 334 mg/kg/day. In contrast, it was only 89 mg/kg/day, which makes a great difference and probably explains why the addition and supplementation of external lactoferrin may not be critical when a baby is already receiving such a big amount of natural lactoferrin.



Slide 40 – Is Mother's Own Milk Lactoferrin Intake Associated With Reduced Neonatal Sepsis, Necrotizing Enterocolitis, and Death?

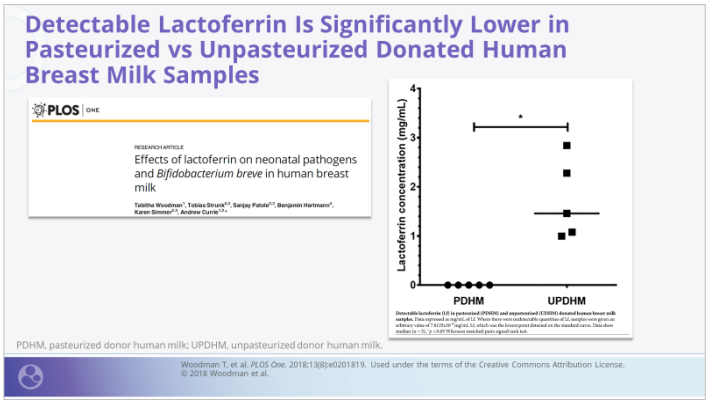
Lactoferrin stability

Two additional findings: please consider that lactoferrin decreases in concentration in stored human milk. If you are feeding a baby with stored human milk, you cannot rely on the same intakes of lactoferrin as if it was in fresh human milk. With breastfeeding, compared to giving stored human milk, there is a reduction of 50%,[39] and even more,



Slide 41 – Stability of Lactoferrin in Stored Human Milk

if lactoferrin undergoes pasteurization. Donated human milk undergoing pasteurization, as it occurs regularly and routinely, has a dramatic decrease in concentration of lactoferrin. Something that does not enable us to provide a protective effect of lactoferrin in this human milk sample.[40]

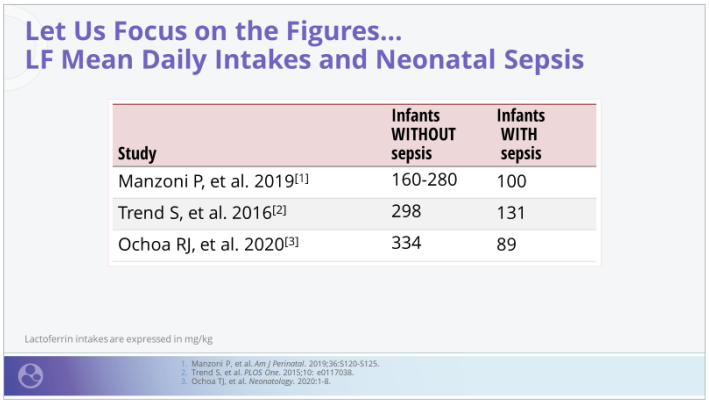


Slide 42 – Detectable Lactoferrin Is Significantly Lower in Pasteurized vs Unpasteurized Donated Human Breast Milk Samples

Beneficial feeding regimens with lactoferrin

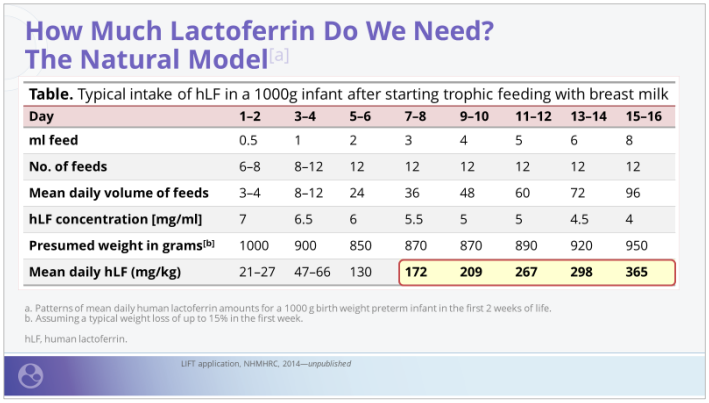
This is summarizing the flow of the last slides, and we are getting to the conclusion. If the goal of this presentation is to give advice about which are the most beneficial feeding regimens with lactoferrin,

please note that according to 3 different studies on 3 different populations [Slide 43],[36-38] infants without sepsis in the first 4 weeks of life receive 300 mg/kg/day of lactoferrin as a mean daily intake. Infants with sepsis, in contrast, receive no more than 100 mg/kg/day. That is only 30%, a two-thirds reduction. This might be the key to understand what we need to do.



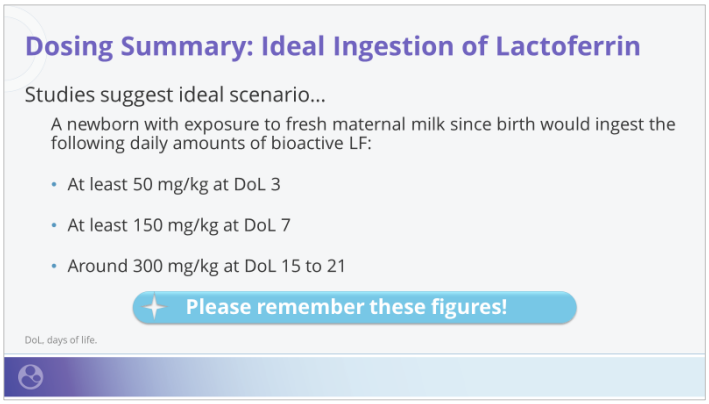
Slide 43 – Let Us Focus on the Figures... LF Mean Daily Intakes and Neonatal Sepsis

And, once more, we had already foreseen and designed this issue when the application for the LIFT trial was placed 7 years ago. In fact, we had nicely estimated the actual daily intakes of human lactoferrin in babies who are regularly and routinely fed with fresh human milk. It's already around 200 mg daily [term], and it's getting up to more than 300 mg when the baby is 2-weeks old. I dare say that these intakes are the correct intakes we need to target in order to have a protective effect.



Slide 44 – How Much Lactoferrin Do We Need? The Natural Model

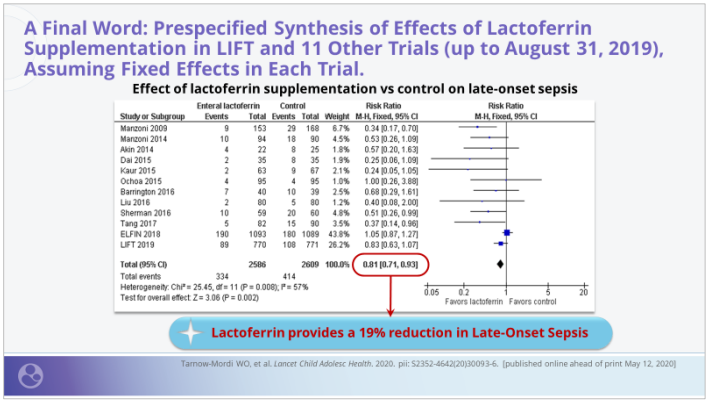
Once these intakes are achieved—and this is another summary of what I was telling you—remember these figures because when these intakes are achieved, thanks to fresh human milk, it's probably not useful to give additional lactoferrin.



Slide 45 – Dosing Summary: Ideal Ingestion of Lactoferrin

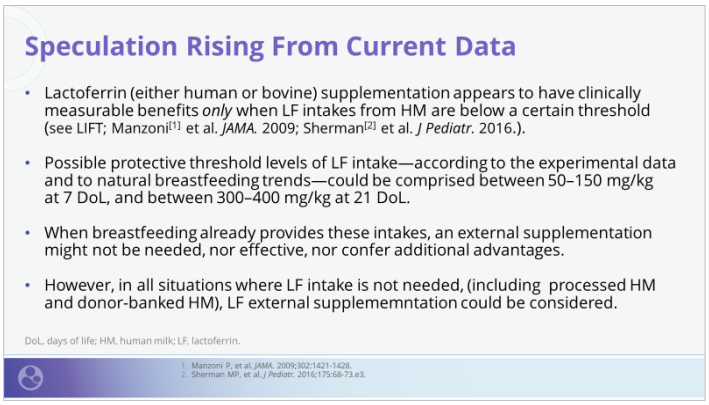
I want to leave you with this very recent (included in the LIFT paper) meta-analysis, which has been able to include, not only the previous studies but also the ELFIN and the LIFT trials [Slide 46]. Now we have more than 5,000 infants; very low-birth-weight infants were randomized to lactoferrin or placebo over 10 years coming from 11 different studies.[41]

The evidence is solid enough to say that lactoferrin prevents infections with a decrease by 19%. It's not a great decrease, but it's actually significant within a very narrow interval of confidence. And this might be the final word prompting speculations.



Slide 46 – A Final Word: Prespecified Synthesis of Effects of Lactoferrin Supplementation in LIFT and 11 Other Trials

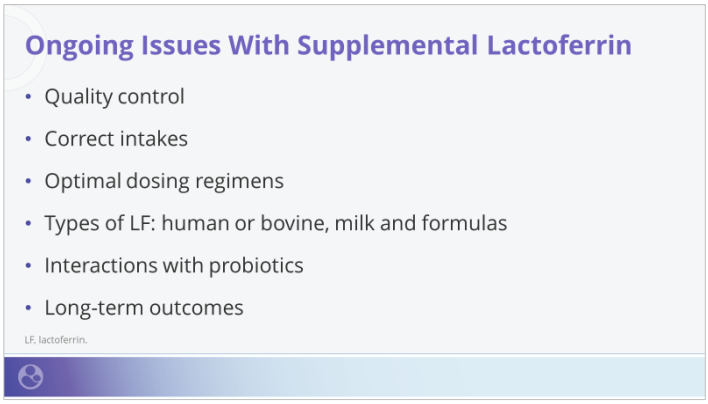
I would dare to say once more that bovine lactoferrin supplementation may give clinically measurable benefits only when lactoferrin intakes of human milk are below a certain threshold, and this occurs with pasteurized, stored, refrigerated human milk or with donor milk, or even less with formula milk.



Slide 47 – Speculation Rising From Current Data

We were able to capture the current protective threshold levels of lactoferrin intake, thanks to the 3 studies I was showing you, and thanks to the analysis of the findings of different trials that assessed different populations with different dosing regimens. Therefore, my advice is that in all situations where breastfeeding is already providing these intakes, an external supplementation with lactoferrin might not be needed or, in any case, might not be able to provide additional advantages.

In contrast, in all situations where lactoferrin intake is not the one that we estimate, that we need as preventative, is not optimal… we need to consider supplementation with external lactoferrin.



Slide 48 – Ongoing Issues With Supplemental Lactoferrin

We need to understand that giving bovine lactoferrin is safe (as of today), and that we can expect the results only when human lactoferrin is not given in the correct amounts.

And finally, before going further, we need also to clarify further points about the quality control, about the dosing regimens, and about the interactions with probiotics because all these areas are critical when we want to establish a feeding regimen with a supplementation that might enhance the protective effect of human milk.

Question & Answer

Editor's Note: This is a transcript of audience questions together with Dr. Manzoni's responses from the May 20, 2020 audio webcast.

Is there a role for lactoferrin in COVID-19 prevention management or treatment in preterm or term infants?

Dr. Manzoni: This is a very timely question. We actually have some scattered data on the ability of lactoferrin to interfere with the MERS coronavirus. The MERS coronavirus is closely similar to the COVID-19, so we may expect that some action of lactoferrin could be envisaged on coronavirus.

Clearly, we need time and studies to understand whether this antiviral effect of lactoferrin is actually there.

How does lactoferrin promote growth of intestinal microbiota to establish and restore healthy microbiota?

Well, lactoferrin acts like a prebiotic. Prebiotics are defined as food for probiotics. In other terms, they are compounds, both chemical or other natural compounds, that are critical to allow probiotics to proliferate. Lactoferrin does this by stimulating the proliferation of specific colonies of probiotics, specific strains namely, *bifidobacteria* and *lactobacilli*. These strains have been most implicated with the benefits in human beings, especially in the first weeks of life.

What is the most significant benefit of lactoferrin for neonates?

Well, certainly the most significant one is the prevention of sepsis, which is a result of the varying and several anti-infective actions of lactoferrin. Of course, human milk is a very complex compound. We cannot extrapolate one single compound of human milk and attribute the benefit of human milk to that single compound. But it's presumable in a complex context, like the one I was showing you. Some compounds have different roles, and in this view, lactoferrin has a critical role in preventing infection.

How much does human breast milk vary in the amount of lactoferrin produced? And is the production of lactoferrin consistent in human breast milk?

Yes. There are 2 different trends that can also mix with each other and interfere with each other. The first trend you mention, lactation. Usually more lactoferrin in the first days, in colostrum in the first days, then decreasing intermediate, and final decrease in natural milk. And another trend is related to the gestational age of the baby. These mothers of premature infants may maintain higher levels of lactoferrin over the duration of their breastfeeding compared with what occurs should the baby be born at term. This might be an interesting mechanism of Mother Nature to provide benefits of lactoferrin even longer than what occurs for those babies more at risk of infection because they have been born prematurely.

Is lactoferrin retained in pasteurized donor milk after processing at the milk bank?

This is a critical point because it's known that pasteurization, also Holder pasteurization decreases by 30% to 60% the amount of lactoferrin contained in the sample because pasteurization has a denaturing ability. So, lactoferrin does not escape this ability of pasteurization. The point is to identify methods of pasteurization that could be more gentle towards critical proteins, such as lactoferrin, or, in contrast, to design strategies of supplementation of lactoferrin whenever the milk is pasteurized.

When should breast milk be supplemented with bovine lactoferrin?

We need to be very accurate with the wording here because if we speak about breast milk—and we mean milk taken by an infant through breastfeeding—we mean fresh human milk. And therefore, supplementation with bovine lactoferrin probably is not needed, thanks to all the data and all the considerations that I was showing you. But if breast milk is expressed human milk that goes to storage and/or to refrigeration, because mothers are expressing milk and storing it in the refrigerator for 20 days because they have to go back to work, this might be a different issue. And in my opinion, in these cases, the decrease of lactoferrin content compared with the original samples could be much higher that it could be applicable to supplement lactoferrin in those samples.

What is the minimum threshold or intake of human lactoferrin that requires bovine lactoferrin supplementation?

Well, again we could speculate on that, and we could identify threshold levels of 70, 80, 90 mg/kg/day. Below these levels, infants are significantly more likely to develop sepsis. If a baby is getting less than these intakes, in my opinion, this baby would need an external supplementation.

In the ELFIN trial, there are 2 serious adverse events that authors reported as possibly associated with lactoferrin use. What are your thoughts?

Well, I think I cannot respond to that. If they were reporting on possibly regular lactoferrin, this might be the case. In any case, it's curious that the lactoferrin proved pace in all the other 11 trials, which means 9,000 infants were randomized, so far. In addition, let's consider that lactoferrin is naturally given to neonates since the Stone Age. So, it would be absolutely unreasonable that there would be a safety issue for this protein, which is naturally occurring within human beings for such a long time.

It is true that we are talking about bovine lactoferrin, but anyway, the homology of biochemical structure is very high. And notably there is, to my knowledge and to the knowledge of the most of us, no reported allergy to lactoferrin. Lactoferrin is not a serum protein of milk; it's not a lactic casein. It's a different kind of protein; it's a glycoprotein. In pediatrics, we never saw allergies to lactoferrin.

Lactoferrin has iron-binding characteristics. What do you recommend in terms of lactoferrin use and iron supplementation for example, dose of iron timing of starting the supplementation if an infant is given lactoferrin supplement?

Well, this is a very important question. Since lactoferrin's iron-binding ability is there to steal iron from the pathogens, it's clear that if we provide iron to the medium, and lactoferrin saturates with the iron that we are providing externally, probably there's no more room for lactoferrin to steal iron from the pathogens. My recommendation and the recommendation of everyone is not to give lactoferrin together with iron. It's not only in several studies, especially in women during pregnancy, it has been seen that lactoferrin itself has good activity promoting iron storage and restoring anemia in sideropenic anemia during pregnancy. My strong suggestion is absolutely not to give iron to infants treated with lactoferrin, or to consider giving iron for different periods.

Is there any research showing the role of lactoferrin for infants who were not born early?

Yes, there are. There is data showing that lactoferrin is able to provide the benefits of several types, also in term infants and in infants during the first year of life, in toddlers, in infants between 1 and 2 years of age. In these other populations, the effect of lactoferrin might be both for respiratory tract infection, as shown in a study from 2007, and in gastrointestinal morbidity, as shown in several studies conducted by the Peruvian group.

It's important to remember that lactoferrin is there when phlogistic reaction occurs. Lactoferrin has an anti-inflammatory activity that might justify a role also in an immunocompetent infant who actually needs management over their immunocompetence, rather than a replacement of their competency.

Are there drug supplements we give infants—iron and others—that could interfere with the apo- or holo-forms of lactoferrin and, in turn, the results of studies?

Yes, this is a very interesting point. I can tell you... I can answer this question by addressing the more general issue of stability and the pharmaceutical form of lactoferrin. This is something we absolutely need. The problem is that when you rely on lactoferrin produced by manufacturers, you may

find different rates of saturation and different balances for apo- and holo-forms of lactoferrin. This is a problem, because these products are not comparable. I advocate for new studies and new regulations clearly re-forming [those] that are the commercial preparations of lactoferrin when this is given as a supplement. Otherwise, we cannot expect the full pattern of benefits to be displayed.

Do you support a role of lactoferrin to protect from bronchiolitis as suggested in Ochoa's trial?

Yes. More generally speaking, there are data, at least from 3 studies so far, showing that in the first year of life supplementation on a daily basis with lactoferrin given through formula milking, which through lactoferrin is able to prevent upper and lower respiratory tract infections, and it heals bronchiolitis, too. Of course, this is not probably attributable to a specific antiviral action, nor to a specific anti-RSV [respiratory syncytial virus] action of lactoferrin, but rather to immunomodulation or mucosal secretion of lactoferrin, just like it occurs in the tears or in saliva.

Is there any cohort of neonates who cannot tolerate lactoferrin?

No. This has not yet been described. And again, I would be very surprised should these kinds of neonates exist, because if we think once to the history of mankind and humanity, lactoferrin has been there. It's not a new compound. It's not something we created in a laboratory 20 years ago. [It is] something that existed forever; it's something that existed both in human milk and in cow milk or in goat milk since forever. So, the point is only to understand whether a little more concentrated intake of lactoferrin might exert issues in terms of toleration. But it would be quite unlikely to expect serious issues about that.

Does lactoferrin have any effect on growth velocity?

No. This is not occurring, and this is absolutely consistent with the characteristics of lactoferrin. Lactoferrin is not acting as a nutritional compound but rather as anti-infective or bioactive compound, better to say. This is something different.

When can we anticipate long-term outcomes from bovine lactoferrin and low-birth-weight formula?

Well, long-term outcomes might be a little difficult to target and to show because the only long-term outcome I can envision is a composite quality of the neurodevelopmental, neurocognitive patterns attributable to the fact that the infant was not affected by sepsis during the NICU stay. It has been shown that infections occurring in the NICU stay in very low-birth-weight infants, impact the quality of neurodevelopmental patterns, determining impairments both in neurological and in cognitive areas. However, it has not yet been shown that by preventing sepsis, there can be any improvement. This is a more complex issue, and I'm sincerely a little less skeptical on the possibility to show long-term outcomes significantly affected by a single compound given in the very first weeks of life. This is true for lactoferrin, but for whichever compound.

Abbreviations

BPD	Bronchopulmonary disease	**MERS**	Middle East Respiratory Syndrome
CMV	Cytomegalovirus	**NEC**	Necrotizing enterocolitis
LOS	Late-onset sepsis	**NICU**	Neonatal Intensive Care Unit
LPS	Lipopolysaccharide	**ROP**	Retinopathy of prematurity

LTA	Lipoteichoic acid	**RSV**	Respiratory syncytial virus

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