Is Lactoferrin More Effective in Reducing Late-Onset Sepsis in Preterm Neonates Fed Formula Than in Those Receiving Mother’s Own Milk? Secondary Analyses of Two Multicenter Randomized Controlled Trials

Paolo Manzoni, MD1,2,* Maria Angela Militello, MD1 Stefano Rizzollo, MD1 Elena Tavella, MD2 Alessandro Messina, MD2 Marta Pieretto, MD2 Elena Boano, MD2 Martina Carlino, MD2 Eleonora Tognato, MD1 Roberta Spola, MD1 Anna Perona, MD1 Milena Maria Maule, MD3 Ruben García Sánchez, MD4 Mike Meyer, MD5 Ilaria Stolfi, MD6 Lorenza Pugni, MD7 Hubert Messner, MD8 Silvia Cattani, MD9 Pasqua Maria Betta, MD10 Luigi Mero, MD11 Lidia Decembrino, MD12 Lina Bollani, MD12 Matteo Rinaldi, MD13 Maria Fioretti, MD14 Michele Quercia, MD15 Chryssoula Tzialla, MD12 Nicola Laforgia, MD14 Fabio Mosca, MD7,16 Rosario Magaldi, MD13 Michael Mostert, MD17 Daniele Farina, MD1 William Tarnow-Mordi, MD18 on behalf of the Italian Task Force for the Study Prevention of Neonatal Fungal Infections; the Italian Society of Neonatology

1 Division of Pediatrics and Neonatology, Department of Maternal, Neonatal, and Infant Medicine, Nuovo Ospedale Degli Infermi, Biella, Italy
2 Neonatology and NICU, Sant’Anna Hospital, AOU Città della Salute e della Scienza, Torino, Italy
3 Cancer Epidemiology Unit, Department of Medical Sciences, University of Turin, Torino, Italy
4 Department of Neonatology and NICU, Complejo Asistencial Universitario de Salamanca, Salamanca, Spain
5 Department of Neonatology and NICU, Middleton Hospital, Auckland, New Zealand
6 Department of Neonatology, Azienda Ospedaliera Universitaria Policlinico Umberto I, Roma, Italy
7 Fondazione IRCCS Ca’ Granda Ospedale Maggiore Policlinico, NICO, Milan, Italy
8 Department of Neonatology and NICU, Ospedale Regionale, Bolzano/Bozen, Italy
9 NICU, University of Modena and Reggio Emilia, Modena, Italy
10 NICU, Azienda Ospedaliera Universitaria Policlinico di Catania, Catania, Italy

Address for correspondence Paolo Manzoni, MD, Division of Pediatrics and Neonatology, Department of Maternal, Neonatal, and Infant Medicine, Nuovo Ospedale Degli Infermi, Via dei Ponderanesi, 2, 13875 Ponderano, Biella, Italy (e-mail: paolomanzoni@hotmail.com).

11 U.O.C. di Pediatria e Patologia Neonatale, Ospedale San Martino, Belluno, Italy
12 UOC Neonatologia e Terapia Intensiva, IRCCS Policlinico San Matteo, Pavia, Italy
13 Department of Neonatology, Ospedali Riuniti, Foggia, Italy
14 Terapia Intensiva Neonatale, Ospedale Monaldi-Azienda Ospedaliera dei Colli, Napoli, Italy
15 Neonatology and Neonatal Intensive Care Unit, Department of Biomedical Sciences and Human Oncology, University of Bari, Bari, Italy
16 Department of Clinical Sciences and Community Health, University of Milan, Milan, Italy
17 Department of Pediatrics, University of Turin, Torino, Italy
18 NHMRC Clinical Trials Centre, University of Sydney, Sydney, New South Wales, Australia


Abstract

Background Lactoferrin is the major antimicrobial protein in human milk. In our randomized controlled trial (RCT) of bovine lactoferrin (BLF) supplementation in preterm neonates, BLF reduced late-onset sepsis (LOS). Mother’s own milk (MM) contains higher concentrations of lactoferrin than donor milk or formula, but whether BLF is more effective in infants who receive formula or donor milk is uncertain.

Aim To evaluate the incidence of LOS in preterm infants fed MM and in those fed formula and/or donor milk.

Study Design This is a (A) post hoc subgroup analysis, in our RCT of BLF, of its effects in preterm infants fed MM, with or without formula, versus those fed formula and/or donor milk (no-MM) and (B) post hoc meta-analysis, in our RCT of BLF and in the ELFIN

* Paolo Manzoni wrote the first draft of the manuscript.
Lactoferrin (LF) is a bioactive milk protein, with major immunological, antimicrobial, and gut maturational effects. Bovine LF (BLF) and human LF have high biochemical homology and share the same N-terminal, 11-aminoacidic peptide, which has antimicrobial antibioticlike properties. Several randomized controlled trials (RCTs) suggest that BLF supplementation can reduce late-onset sepsis (LOS) in preterm neonates in NICU.\(^1\)–\(^6\) However, these data are rated as low- to moderate-quality in a Cochrane review\(^7\) and seem to be inconsistent with a recent RCT in 2,203 preterm infants that found no effect of BLF supplementation on LOS.\(^8\)

Human colostrum is rich in LF, with concentrations five- to sixfold higher than that in mature milk.\(^9\) Infants fed since birth with fresh milk from their mother might therefore receive adequate quantities of LF. In a case–control study in 97 preterm infants, those who developed LOS had consumed significantly less breast milk and lower doses of LF and other milk antimicrobial proteins than the controls.\(^10\)

In our original RCT of BLF supplementation in preterm infants,\(^1\) we collected nutritional data and reported days of exposure to, as well as intakes of, human milk, donor milk, and formula milk for all patients. There were no differences in the relative proportions of mother’s own milk (MM) fed and formula/donor milk fed infants between the three randomization groups (BLF alone, BLF + the probiotic Lactobacillus rhamnosus GG [LGG], placebo). We showed a significant protective effect of BLF that remained independent of the type of feeding after multiple logistic regression analysis.

In this exploratory analysis, we evaluated the hypothesis that lactoferrin may be more effective in reducing LOS in preterm infants who receive a lower proportion of their own mother’s milk.

Materials and Methods

(A) This was a secondary analysis of data obtained during a multicenter RCT performed in Italy and New Zealand from 2006 to 2008; its original protocol is published previously.\(^1,\)\(^11\) Preterm very low birthweight (VLBW) neonates from 11 tertiary NICUs were enrolled before 72 hours of life and were randomly assigned to receive BLF alone (LF100, Dicofarm SpA, Rome, Italy; 100 mg/day, group A1) or in combination with LGG (Dicoflor60, Dicofarm SpA, Rome, Italy; 10\(^6\) colony-forming units per day, group A2) or placebo (group B) from birth to DOL 30 (DOL 45 for those <1,000 g at birth). The drugs and placebo were administered orally once a day. Neonates not feeding in the first 48 hours received the drug(s)/placebo by orogastric tube. Results from this RCT showed that BLF supplementation, alone or in combination with LGG, reduces the risk of LOS and necrotizing enterocolitis\(^3\) in VLBW infants compared with placebo.

Per protocol, clinical and management data were collected prospectively for all enrolled infants until death or discharge. Systematic clinical surveillance for adverse events was performed through daily infant examination until 2 days after the end of treatment.

Nutritional and feeding policies were stable during the study and consistent among centers, following common guidelines and adherence to the study protocol. In particular, the use of fresh MM was encouraged; when it was not available, the neonates were fed either a standard preterm milk formula, not supplemented with LF,\(^1\) and/or with donor milk obtained through processing (including 62.5°C Holder pasteurization, followed by refrigeration) of pooled milk.

Clinical surveillance for the detection of sepsis was performed in all enrolled infants, with complete laboratory and microbiology evaluation in case of suspected LOS.

In this secondary analysis, the primary aim was to test the hypothesis that BLF has a lower impact in reducing LOS in infants who receive MM than in those who receive formula or donor milk.

Standard laboratory methods were used to identify bacteria from cultures.\(^12\) For Candida species, specimens were...
incubated on chromogen culture plates (Albicans ID, bioMérieux, Marcy l’Etoile, France) to identify Candida albicans blue staining colonies after 48 hours of incubation at 37°C. Colonies were speciated biochemically (Vitec Yeast, bioMérieux).

The criteria for hospital discharge were birthweight of 1,800 g, full oral feeding, and resolution of acute medical conditions. Sepsis episodes were treated with antibiotics/antifungal agents in accordance with the existing literature, guidelines from international consensus documents, and the Italian Neonatology Society’s Fungal Infections Task Force recommendations.4 Blinding was not broken to guide therapy.

Infants who received fresh MM, exclusively or with formula or donor milk, were compared with those not exposed to MM (no-MM, i.e. formula milk and/or donor milk) with regard to the incidence of the first episode of LOS in patients receiving or not receiving BLF.

(B) We calculated risk ratios (i.e., RRs) and 95% CIs for LOS after BLF treatment in infants receiving MM (RR: 0.34; 95% CI: 0.18–0.64) was almost double than that of those infants not receiving MM (RR: 0.19; 95% CI: 0.04–0.84) (Tables 1–4).

In the multivariable logistic regression model, the point estimate for the odds of LOS associated with BLF treatment was more than doubled in infants who received MM (OR: 0.38 for BLF and 0.22 for BLF + LGG vs. placebo) than those who did not (OR: 0.12 for BLF and 0.15 for BLF + LGG vs. placebo). However, the introduction of an interaction term between type of feeding and treatment did not improve the model fit significantly (likelihood ratio test p-value: 0.628), indicating no significant interaction (Tables 5 and 6).

(B) In 1,891 infants not exclusively fed MM in our RCT of BLF and in the ELFIN RCT, BLF reduced the RR of LOS by 18% (RR: 0.82; 95% CI: 0.71–0.96; p = 0.01) (Fig. 2). When cases of fungal sepsis were excluded from the analysis, the RR for LOS after BLF treatment was 0.85 (95% CI: 0.73–0.99; p = 0.04).

Discussion

Our hypothesis was that receiving MM may reduce the effect of BLF on LOS. In analysis A, univariable analyses are consistent with this hypothesis, but multivariable logistic regression analysis does not confirm it as there was no significant interaction between feeding type and BLF treatment. In analysis B, there was evidence that BLF may reduce LOS in infants not exclusively receiving MM.

Our results are therefore consistent with data showing that human milk has a protective effect against infection.

Table 1 Univariable analysis of BLF and LOS in infants receiving mother’s own milk: BLF treatments combined versus placebo

<table>
<thead>
<tr>
<th>Groups (total n = 383)</th>
<th>A1 + A2 vs. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLF + LGG (A1 + A2), n = 250</td>
<td>Placebo (B), n = 133</td>
</tr>
<tr>
<td>RR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Total LOS (n = 36)</td>
<td>14/250 (5.6%)</td>
</tr>
</tbody>
</table>

Abbreviations: BLF, bovine lactoferrin; CI, confidence interval; LGG, Lactobacillus rhamnosus GG; LOS, late-onset sepsis; RR, relative risk.

References


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Screened and assessed for eligibility \( (n = 494) \)

Excluded \( (n = 22) \)
- Incomplete data on type of feeding \( (n = 22) \)

Is it randomized?

Allocated to BLF \((n = 304; n = 153\) in A1; \(n = 151\) in A2)
- Received allocated intervention
  \((n = 304; n = 153\) in A1; \(n = 151\) in A2)
- Did not receive allocated intervention \((n = 0)\)

Allocated to PLACEBO \((n = 168)\)
- Received placebo \((n = 168)\)
- Did not receive placebo \((n = 0)\)

Exposed to mother’s own milk \((127\) in A1; \(123\) in A2; Total = 250)
Not exposed to mother’s own milk \((26\) in A1; \(28\) in A2; Total = 54)

Analyzed \((n = 304)\)
\((n = 153\) in A1; \(n = 151\) in A2)

Exposed to mother’s own milk \((n = 133)\)
Not exposed to mother’s own milk \((n = 35)\)

Analyzed \((n = 168)\)

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**Fig. 1** CONSORT (Consolidated Standards of Reporting Trials) e-flowchart.

**Table 2** Univariable analysis of BLF and LOS in infants fed MM

<table>
<thead>
<tr>
<th>Groups (total ( n = 383 ))</th>
<th>A1 vs. B</th>
<th>A2 vs. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>( BLF (A1), n = 127 )</td>
<td>( BLF + LGG (A2), n = 123 )</td>
<td>( Placebo (B), n = 133 )</td>
</tr>
<tr>
<td>Total LOS ((n = 36))</td>
<td>( 8/127 ) (6.3%)</td>
<td>( 6/123 ) (4.9%)</td>
</tr>
<tr>
<td>RR</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>95% CI</td>
<td>0.17–0.82</td>
<td>0.17–0.82</td>
</tr>
<tr>
<td>( p )-Value</td>
<td>0.011</td>
<td>0.011</td>
</tr>
</tbody>
</table>

**Abbreviations:** BLF, bovine lactoferrin; CI, confidence interval; LOS, late-onset sepsis; MM, mother’s own milk; RR, relative risk.

**Table 3** Univariable analysis of BLF and LOS in infants not fed MM

<table>
<thead>
<tr>
<th>Groups (total ( n = 89 ))</th>
<th>A1 vs. B</th>
<th>A2 vs. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>( BLF (A1), n = 26 )</td>
<td>( BLF + LGG (A2), n = 28 )</td>
<td>( Placebo (B), n = 35 )</td>
</tr>
<tr>
<td>Total LOS ((n = 9))</td>
<td>( 1/26 ) (3.8%)</td>
<td>( 1/28 ) (3.6%)</td>
</tr>
<tr>
<td>RR</td>
<td>0.19</td>
<td>0.19</td>
</tr>
<tr>
<td>95% CI</td>
<td>0.03–1.47</td>
<td>0.03–1.47</td>
</tr>
<tr>
<td>( p )-Value</td>
<td>0.122</td>
<td>0.122</td>
</tr>
</tbody>
</table>

**Abbreviations:** BLF, bovine lactoferrin; CI, confidence interval; LGG, Lactobacillus rhamnosus GG; LOS, late-onset sepsis; MM, mother’s own milk; RR, relative risk.
and that this beneficial effect may be related to cumulative intake, with intake thresholds that confer significant protection compared with lower intakes. In a retrospective case–control study, Trend et al showed that infants who experienced LOS were exposed to lower cumulative intakes of lactoferrin through human milk than controls. That study demonstrated that the average consumption of LF by infants without LOS was 300 to 800 mg/kg/day, which is much

**Table 4** Univariable analysis of BLF and LOS in infants not receiving MM: BLF treatments combined versus placebo

<table>
<thead>
<tr>
<th>Groups (total n = 89)</th>
<th>A1/A2 vs. B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
</tr>
<tr>
<td>Total LOS (n = 9)</td>
<td></td>
</tr>
<tr>
<td>BLF + LGG (A1 + A2), n = 54</td>
<td>2/54 (3.7%)</td>
</tr>
<tr>
<td>Placebo (B), n = 35</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BLF, bovine lactoferrin; CI, confidence interval; LGG, Lactobacillus rhamnosus GG; LOS, late-onset sepsis; MM, mother’s own milk; RR, relative risk.

**Table 5** Multivariable logistic regression analysis controlling for the most important risk factors possibly associated with LOS

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLF and MM (referent: placebo and formula or donor milk (no-MM))</td>
<td>0.38</td>
<td>0.15</td>
<td>0.96</td>
</tr>
<tr>
<td>BLF + LGG and MM (referent: placebo and formula or donor milk (no-MM))</td>
<td>0.22</td>
<td>0.08</td>
<td>0.64</td>
</tr>
<tr>
<td>Sex (referent: male)</td>
<td>1.85</td>
<td>0.87</td>
<td>3.96</td>
</tr>
<tr>
<td>Gestational age (weeks)*</td>
<td>0.70</td>
<td>0.57</td>
<td>0.88</td>
</tr>
<tr>
<td>Birthweight (grams)*</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Use of H2 blockers (total days)*</td>
<td>1.03</td>
<td>0.99</td>
<td>1.08</td>
</tr>
<tr>
<td>Use of postnatal steroids (total days)*</td>
<td>1.10</td>
<td>0.54</td>
<td>2.22</td>
</tr>
<tr>
<td>Daily average amounts of MM intake (mL/kg)</td>
<td>1.00</td>
<td>0.98</td>
<td>1.01</td>
</tr>
</tbody>
</table>

Abbreviations: BLF, bovine lactoferrin; CI, confidence interval; LGG, Lactobacillus rhamnosus GG; LOS, late-onset sepsis; MM, mother’s own milk; OR, odds ratio.

*OR for a one-unit increase.

**Table 6** Interaction between type of milk feeding and BLF treatment

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction milk and treatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1 (referent: placebo) in infants fed no MM</td>
<td>0.12</td>
<td>0.01</td>
<td>1.23</td>
</tr>
<tr>
<td>A2 (referent: placebo) in infants fed no MM</td>
<td>0.15</td>
<td>0.02</td>
<td>1.59</td>
</tr>
<tr>
<td>Milk type: maternal (referent: nonmaternal) in infants treated with placebo</td>
<td>0.91</td>
<td>0.21</td>
<td>3.96</td>
</tr>
</tbody>
</table>

Abbreviations: BLF, bovine lactoferrin; CI, confidence interval; OR, odds ratio.

Note: p-Value of likelihood ratio statistic to detect any interaction between treatment and type of feeding: 0.628. Within-center correlation: 4.2%; p-value: 0.18.

**Fig. 2** Meta-analysis of the effect of bovine lactoferrin on late-onset sepsis in 1,891 preterm infants who were not exclusively fed mother’s own milk in two RCTs of lactoferrin supplementation. In Fig. 2 of the original ELFIN trial report, the subtotals 10/ 53 and 12/60 in the subgroup analysis for infants fed formula only were incorrectly transposed between the groups randomized to lactoferrin and control, producing a risk ratio of 1.06 instead of 0.94. This error is corrected in the diagram shown here. CI, confidence interval; ELFIN, Enteral Lactoferrin in Neonates. (Adapted from ELFIN Trial Investigators Group.)

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higher (three- to fourfold) than the LF consumed by infants who had sepsis. In the same study, fresh breast milk samples and formula were also assessed for their antimicrobial properties in in vitro experiments. Specific threshold LF levels consistent with the intakes coming from breast fresh milk were needed to limit pathogen growth and hence achieve clinical protection from sepsis.

It is known that colostrum and intermediate milk are rich in LF compared with mature milk and that this may be even more true with human milk from mothers of premature infants. Our group has calculated that exposure to LF through human milk in a well premature infant could rapidly increase to some 100 to 150 mg/day soon after the first week of life if the baby tolerates full feeds with MM from soon after birth.11

These findings suggest that intakes of LF in excess to those already delivered by MM might not confer an additional advantage, being in line with the assumption that concentrations in colostrum and MM should be naturally tailored for the needs of the infant. In contrast, LF supplementation replacing the gap in intakes in those babies not receiving the correct amounts of MM (as in infants fed formula or fed donor processed milk) could improve protection from infections.

These data may help reconcile the inconsistencies between LF studies in the past 12 years and the UK ELFIN trial including 2,203 preterm infants, which reported no reduction in LOS after BLF treatment.8 One reason for the difference between our earlier trial in 20091 and the ELFIN trial8 may be a reduction in the use of formula only from 15% in our trial to 5% in ELFIN. The hypothesis that BLF is more effective in infants not receiving MM could be evaluated further in an individual participant data meta-analysis of published studies.

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Conflict of Interest
None declared.

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