Preterm infant outcomes in relation to the gestational age of onset and duration of prelabour rupture of membranes: a retrospective cohort study

Pramod Pharande,1,2 Mohamed E Abdel-Latif,3,4 Barbara Bajuk,5 Kei Lui,1,2 Srinivas Bolisetty,1,2 on behalf of the New South Wales and Australian Capital Territory Neonatal Intensive Care Units Audit Group


ABSTRACT

Objective To determine the hospital outcomes of liveborn infants at 23–31 weeks following prelabour preterm rupture of membranes (PPROM).

Method A regional retrospective cohort study of 4454 infants of 23–31 weeks’ gestation admitted to a tertiary neonatal network between 2007 and 2011. Primary outcome was the composite chronic lung disease (CLD) or mortality at discharge.

Results 225 (5%) neonates had a history of PPROM occurring prior to 2416 weeks (Early-PPROM), 829 (19%) had a history of PPROM at or after 2416 weeks’ gestation (Late-PPROM) and 3400 (76%) had no history of PPROM (No-PPROM). In comparison to No-PPROM, Early-PPROM group had higher CLD/mortality in infants born at 23–27 weeks (OR 1.95; 95% CI 1.34 to 2.85) and 28–31 weeks (OR 4.98; 95% CI 2.99 to 8.28). Within Early-PPROM group, the latency of PPROM >14 days had lower CLD/mortality in comparison to latency ≤14 days (57.6% vs 77%, OR 0.40; 95% CI 0.21 to 0.76). Late-PPROM group had significantly lower CLD/mortality in comparison to No-PPROM group at 23–27 weeks (OR 0.50; 95% CI 0.37 to 0.69) and 28–31 weeks (OR 0.50; 95% CI 0.36 to 0.71). Within Late-PPROM group, latency >14 days was associated with an increased CLD/mortality in 28–31 weeks (14.1% vs 5.4%, OR 2.88; 95% CI 1.31 to 6.38).

Conclusions Early-PPROM prior to 24 weeks’ gestation had high incidence of CLD/mortality even after correcting for gestational age. Late-PPROM at or after 24 weeks had lower CLD/mortality with No-PPROM. Latency >14 days in Late-PPROM group at 28–31 week group increased the odds of CLD/mortality.

BACKGROUND

Prelabour preterm rupture of membranes (PPROM) refers to the rupture of amniotic membranes prior to 37 weeks’ gestation and prior to the onset of labour. PPROM occurs in 2%–3% of pregnancies and accounts for 30%–40% of preterm births.1–3

PPROM has been reported to be associated with a fourfold increase in perinatal morbidity and a threefold increase in neonatal morbidity, including respiratory distress syndrome, polymicrobial intra-amniotic infection and intraventricular haemorrhage (IVH).1 4 5 In particular, Early-PPROM occurring before 2416 weeks’ gestation has been reported to carry a high risk of chorioamnionitis and oligohydramnios in affected women with high mortality and morbidity in their neonates.6 In recent years, some institution-based studies reported improved hospital survival rates in preterm infants born following PPROM.7 8 However, there are no large population-based studies to suggest preterm infants born following PPROM have better or worse outcomes in comparison to those born following non-PPROM-related causes.

In this study, we included the latest cohort of extreme preterm infants admitted within a well-defined regional neonatal intensive care unit (NICU) network to test the hypothesis that extreme to very preterm infants born following PPROM have increased hospital mortality in comparison to non-PPROM-related aetiology. We also tested if Early-PPROM occurring before...
24\textsuperscript{0} weeks’ gestation was associated with an increased rate of mortality and/or chronic lung disease (CLD) compared with those with no history of PPROM.

**METHODS**

This is a retrospective cohort study of infants born at <32 weeks’ gestation and admitted to any of the NICUs in New South Wales and the Australian Capital Territory between January 2007 and December 2011. Data were obtained from the Neonatal Intensive Care Units’ Data Collection, an ongoing prospective audit of infants admitted to any of the 10 NICUs in the region. Neonates with major congenital malformations or chromosomal anomalies were excluded.

Pulmonary hypoplasia was defined as a clinical sign of respiratory distress in the first days of life with confirmatory radiological appearance. Radiological presentation of pulmonary hypoplasia consisted of small lung fields with diaphragmatic domes elevated up to the seventh rib and bell-shaped chest.\textsuperscript{9} IVH was graded I–IV using criteria defined by Papile \textit{et al} and retinopathy of prematurity (ROP) by the International Classification of Retinopathy of Prematurity. CLD was defined as the requirement for any respiratory support at 36 weeks’ postmenstrual age. Other definitions and accuracy of the data have been documented previously.\textsuperscript{10}

The primary outcome was the composite of death at hospital discharge and/or CLD.

For study purposes, women with PPROM prior to 24\textsuperscript{0} weeks were defined as Early-PPROM, women with PPROM ≥24\textsuperscript{0} weeks and <32 weeks’ gestation were defined as Late-PPROM and women with no history of PPROM (duration of rupture of membranes <24 hours) were defined as No-PPROM.

**Statistical analysis**

Statistical analyses were performed using SPSS (IBM; SPSS Statistics for Windows, V.22.0.0.0, Released 2013). Categorical outcome data are presented as percentages with OR and 95% CI. Continuous data were tested for homogeneity of variance using Levene’s test. Non-parametric variables were compared using either Mann-Whitney U test (for two-group comparison) or Kruskal-Wallis test (for multiple group comparison). Parametric variables were compared using either ‘t’ test (for two-group comparison) or analysis of variance (for multiple group comparison).

Multivariable logistic regression models were used to control for confounding factors and to elicit any independent influences. A two-tailed P value <0.05 was considered to be statistically significant.

**RESULTS**

Between 1 January 2007 and 31 December 2011, there were a total of 4501 preterm infants born at less than 32 weeks and admitted to participating NICUs. Forty-seven neonates were excluded and they comprised 44 neonates with major congenital anomalies, 2 neonates at 22 weeks and 1 neonate born at 24 weeks but admitted to NICU for palliative care. Of the remaining 4454 neonates included in the study, 225 (5.1%) had a history of the onset of PPROM <24\textsuperscript{0} weeks’ gestation (Early-PPROM), 829 (18.6%) had a history of PPROM ≥24\textsuperscript{0} weeks’ gestation (Late-PPROM) and 3400 (76.3%) had no history of PPROM (duration of rupture of membranes <24 hours).

![Flow chart of the study population. NICUS, Neonatal Intensive Care Units’ Data Collection; PPROM, prelabour preterm rupture of membranes.](http://bmjpaedsopen.bmj.com)
of PPROM (No-PPROM) (figure 1). Data for the major primary outcomes were complete. Data on postnatal steroid usage and pulmonary hypertension were missing in 40 (1.6%) and 46 (1.9%) infants, respectively. Data on chorioamnionitis (clinical and/or histopathological) were available for 75% of Early-PPROM group.

The maternal and neonatal demographics and characteristics are listed in Table 1. The mean maternal age was higher by 0.57 year in Late-PPROM group in comparison to No-PPROM group. The prevalence of chorioamnionitis was significantly higher in Early-PPROM and Late-PPROM groups compared with No-PPROM group (48.9%, 41.1% and 14.1%, respectively). In Late-PPROM group, chorioamnionitis was significantly higher in the group with latency of PPROM >14 days (55.8% vs 39.8%, P 0.013). The median duration of PPROM of 26.2 days (650 hours) was significantly longer in Early-PPROM group. The prevalence of antepartum haemorrhage (APH) was also significantly higher in Early-PPROM group (33.3%). Antenatal steroid coverage was significantly higher in Early-PPROM (95%) and Late-PPROM (97%) groups compared with No-PPROM (88%) group.

The mean gestational age (GA; 26 weeks) and birth weight (966 g) in the Early-PPROM group were significantly lower compared with other groups. No-PPROM group had a higher number of small for gestational age (SGA, birth weight <10th percentile) neonates than in Late-PPROM and Early-PPROM groups, respectively (9% vs 1.2% and 3.1%).

Neonatal outcomes and interventions are described in Table 2. The Early-PPROM group had a significantly higher prevalence of morbidities: air leaks, pulmonary hypertension, sepsis, patent ductus arteriosus (PDA), IVH ≥ grade III and ROP stage ≥3. This group also had longer duration of respiratory support and hospitalisation and the need for high-frequency oscillation ventilation (HFOV), inhaled nitric oxide (iNO) therapy and home oxygen. However, Late-PPROM group had significantly less prevalence of air leaks, late-onset sepsis, CLD, home oxygen, severe IVH, necrotising enterocolitis,
PDA, severe ROP and less requirement for surfactant, and respiratory support including HFOV in comparison to No-PPROM group. Mortality was significantly less in Late-PPROM group in comparison to No-PPROM group, but the odds of mortality in Early-PPROM group was nearly four times of No-PPROM group.

Table 2 also shows the details of mortality, CLD among survivors and the composite CLD/mortality in three study groups stratified into two groups based on the GA at birth. Overall mortality rates in Early-PPROM, Late-PPROM and No-PPROM groups were 25.3%, 2.8% and 7.8%, respectively. Overall CLD rates in three groups were 39%, 11.3% and 17.7%, respectively. In comparison to No-PPROM group, mortality and CLD rates were significantly higher in Early-PPROM group at both 23–27 weeks’ gestation (31% vs 21% for mortality and 62.7% vs 48.4% for CLD) and 28–31 weeks’ gestation (12% vs 3% for mortality and 31% vs 9.1% for CLD). In contrast, Late-PPROM group had significantly less mortality, CLD and the composite outcome of CLD/mortality in both gestational groups in comparison to No-PPROM group.
Table 3 Chronic lung disease/mortality in relation to latency of PPROM

<table>
<thead>
<tr>
<th>GA at birth, weeks</th>
<th>No-PPROM n=3400</th>
<th>Late-PPROM n=829</th>
<th>Early-PPROM n=225</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤14 days (n=759)†</td>
<td>&gt;14 days (n=70)†</td>
<td>≤14 days (n=74)†</td>
</tr>
<tr>
<td>All</td>
<td>860/3400 (25.3)</td>
<td>109/759 (14.4)</td>
<td>57/74 (77)</td>
</tr>
<tr>
<td></td>
<td>0.49 (0.39, 0.62)***</td>
<td>0.55 (0.28, 1.05)</td>
<td>19.99 (11.21, 35.65)***</td>
</tr>
<tr>
<td>23–27</td>
<td>580/974 (59.5)</td>
<td>78/181 (43)</td>
<td>2/6 (33.3)</td>
</tr>
<tr>
<td></td>
<td>0.51 (0.37, 0.71)***</td>
<td>0.33 (0.06, 1.86)</td>
<td>4.42 (2.39, 8.2)***</td>
</tr>
<tr>
<td>28–31</td>
<td>280/2426 (11.5)</td>
<td>31/578 (5.4)</td>
<td>9/64 (14.1)</td>
</tr>
<tr>
<td></td>
<td>0.43 (0.30, 0.64)***</td>
<td>1.25 (0.61, 2.56)</td>
<td>4.98 (2.99, 8.2)***</td>
</tr>
</tbody>
</table>

Data presented as numbers (%), OR (95% CI) unless indicated otherwise.
*P<0.05; **P<0.01; ***P<0.001.
†In comparison to No-PPROM group.

**Table 3** shows the composite primary outcome in relation to the latency of PPROM. In comparison to No-PPROM group, the Early-PPROM group, irrespective of the latency, showed a significantly higher CLD/mortality risk in both 23–27 and 28–31 weeks’ GA categories; whereas Late-PPROM group had significantly lower CLD/mortality only in latency ≤14 days group in both GA categories.

We conducted a within-group analysis in relation to latency of PPROM. Within Early-PPROM group, latency >14 days had significantly lower CLD/mortality in comparison to latency ≤14 days (57.6% vs 77%, OR 0.40, 95% CI 0.21 to 0.76, P <0.004). Within Late-PPROM group, latency >14 days had a trend towards lower CLD/mortality in 23–27 weeks’ GA category (33% vs 43%, OR 0.66, 95% CI 0.12 to 3.69) but significantly higher CLD/mortality in 28–31 weeks’ GA category (14.1% vs 5.4%, OR 2.88, 95% CI 1.31 to 6.38, P <0.015). Within Early-PPROM group, infants at 28–31 weeks’ GA category had a significantly lower CLD/mortality in comparison to 23–27 weeks’ GA category (39.4% vs 71.8%, OR 0.26, 95% CI 0.13 to 0.5, P <0.001). Within Late-PPROM group, 28–31 weeks’ GA had significantly less CLD/mortality compared with 23–27 weeks’ GA (6.2% vs 42.8%, OR 0.08, 95% CI 0.05 to 0.13, P <0.001). These results are not shown in tables.

Multivariable logistic regression is shown in table 4. Late-PPROM group and antenatal steroids were identified to be independently associated with reduced CLD/mortality, whereas Early-PPROM group, latency >14 days, lower GA category (23–27 weeks), male gender and birth weight <10th percentile were associated with higher CLD/mortality. Latency >14 days in Early-PPROM and Late-PPROM groups increased the adjusted odds of CLD/mortality by twofold.

**DISCUSSION**

To our knowledge, this is the only multicentre study involving a large regional population to report on the most recent outcomes of liveborn infants born to women with a history of PPROM. PPROM is associated with manifold increase in neonatal mortality and morbidity. However, it has not been previously shown whether PPROM would have more adverse outcomes in preterm infants compared with Non-PPROM-related causes of prematurity. Our study shows that PPROM had varied influence on CLD/mortality in preterm infants based on the onset and duration of PPROM. Early-PPROM occurring prior to 24 weeks was associated with a fivefold increase in CLD/mortality in comparison to No-PPROM group. In contrast, Late-PPROM occurring at or after 24 weeks’ GA was associated with 50% less CLD/mortality in comparison to No-PPROM group.

**Table 4** Multivariable analysis to determine the factors associated with chronic lung disease/mortality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted OR (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late-PPROM versus No-PPROM</td>
<td>0.56 (0.43 to 0.72)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Latency &gt;14 days vs ≤14 days</td>
<td>2.58 (1.54 to 4.31)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Early-PPROM versus No-PPROM</td>
<td>1.98 (1.26 to 3.10)</td>
<td>0.003</td>
</tr>
<tr>
<td>Latency &gt;14 days vs ≤14 days</td>
<td>1.92 (1.18 to 3.12)</td>
<td>0.008</td>
</tr>
<tr>
<td>GA 23–27 weeks vs 28–31 weeks</td>
<td>9.45 (7.88 to 11.32)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Antenatal steroids</td>
<td>0.69 (0.53 to 0.91)</td>
<td>0.007</td>
</tr>
<tr>
<td>Chorioamnionitis</td>
<td>1.01 (0.82 to 1.26)</td>
<td>0.896</td>
</tr>
<tr>
<td>Multiple versus singleton</td>
<td>0.92 (0.76 to 1.12)</td>
<td>0.420</td>
</tr>
<tr>
<td>Male versus female gender</td>
<td>1.36 (1.14 to 1.61)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SGA versus AGA</td>
<td>4.65 (3.52 to 6.15)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

AGA: BW ≥10th percentile. SGA: BW <10th percentile.
AGA, appropriate for gestational age; BW, birth weight; GA, gestational age; PPROM, prelabour preterm rupture of membranes; SGA, small for gestational age.
Our study shows an interesting interaction between the latency and onset of PPROM. In Early-PPROM group, latency >14 days was associated with 60% reduction in CLD/mortality in comparison to shorter latency. The improved outcome within this group can be explained by higher gestation at birth. Our findings suggest that the longer the latency in Early-PPROM group, the better the outcome. Therefore, the practice of prolonging the pregnancy as long as possible in Early-PPROM group is justified. A few other small studies suggested a similar trend. Everest et al in a single-centre retrospective study of 40 liveborn infants, reported 70% survival rate to discharge in a group of liveborn infants with a history of PPROM prior to 24 weeks’ gestation plus a latent period of at least 14 days before delivery. Williams et al reported a retrospective case analysis of 23 pregnancies complicated by PPROM prior to 25 weeks’ gestation. They reported survival of 78% in 15 infants who were born after 24 weeks with a latency of >14 days; seven of those infants (78%) responded to HFOV and iNO therapy with good clinical response. Sovyu et al reported a 76% survival to discharge in a group of preterm infants born at <32 weeks following PPROM at <24 weeks’ gestation and a latency of >7 days. Shah and Kluckow reported a 90% survival to discharge in preterm infants born after PPROM at 24 weeks or less with a latent period of 14 days though the cohort consisted of more mature infants (mean GA 27.8±5.3 weeks and birth weight 1207±783 g) when compared with our cohort.

In contrast, Late-PPROM group showed a different interaction based on the GA at birth. The better outcomes (decreased CLD/mortality) in Late-PPROM group can be explained by various factors as Late-PPROM group had higher antenatal steroid coverage (97% vs 88%), was more mature (higher mean GA (29.1 weeks vs 28.6 weeks) and birth weight (1367 g vs 1247 g)) and had significantly less number of SGA infants (1.2% vs 9%) as compared with No-PPROM group. Latency >14 days had no significant influence on CLD/mortality in Late-PPROM infants born at 23–27 weeks. However Late-PPROM group born at 28–31 weeks following latency >14 days was associated with a threefold rise in CLD/mortality (14.1% vs 5.4%, OR 2.88, 95% CI 1.31 to 6.38, P 0.015). A recently published study by Lorthe et al from national population-based EPIPAGE2 cohort of preterm neonates delivered after PPROM at 24–32 weeks’ gestation concludes that for a given GA at birth, prolonged latency duration after PPROM does not worsen neonatal prognosis. A crude association found between prolonged latency duration and improved survival disappeared on adjusting for GA at birth. This contradicts our study findings. The worse neonatal outcomes in Late-PPROM group after latency >14 days may be explained by higher choioamnionitis (55.8% vs 39.8%, P 0.013) in that group.

There were a number of perinatal complications noted in our PPROM groups. APH and choioamnionitis are known complications in pregnancy following PPROM. The prevalence of APH of 33.3% in our Early-PPROM group is within the range reported by other studies. Manuck et al reported an overall placental abruption incidence of 75% in a cohort of 159 women who experienced PPROM before 24 weeks’ gestation and Deutsch et al reported 25% APH in a cohort of 105 women who had mid-trimester PPROM before 24 weeks.

Over 40% of women in the Early-PPROM and Late-PPROM groups in our study had clinical and/or histologically proven choioamnionitis. This was probably an underestimation as data on choioamnionitis were incomplete. This was despite over 78% of women in both PPROM groups receiving antibiotics prior to labour. There were similar findings in other studies. Everest et al reported histological choioamnionitis in 60% of women. Sovyu et al found 30% of women with clinical choioamnionitis and Manuck et al reported 54%. Gomez et al demonstrated that intra-amniotic inflammation can develop despite antibiotic therapy for women with PPROM.

Both respiratory and non-respiratory neonatal morbidities were high in the Early-PPROM group. Nearly 40% of the group developed CLD and 18% were discharged home on oxygen. Many other recent studies also reported a high incidence of CLD ranging from 34% to 55%.

Other respiratory morbidities were also significantly higher in our Early-PPROM group including air leak (10%), postnatal steroids (20%), pulmonary hypertension (21.8%), iNO therapy (20.9%) and prolonged duration of respiratory support. Non-respiratory morbidities were also significantly higher including severe IVH (10.3%), late-onset sepsis (32%) and severe ROP (12.4%).

Many of these morbidities can be explained by the earlier GA of Early-PPROM group, but these morbidities were significantly higher in the Early-PPROM group even after correcting for GA. The mechanism underlying these high morbidities and mortalities in this group can be explained by a combination of altered antenatal lung development, infection and the fetal inflammatory response syndrome (FIRS) induced by PPROM and associated choioamnionitis. Hecht et al demonstrated a strong inflammatory signal in the blood of preterm infants born before 28 weeks’ gestation whose placenta showed histological choioamnionitits. At these early weeks of gestation, spontaneous preterm deliveries without PPROM are known to be associated with intrauterine infection/inflammatory response. FIRS is associated with high rates of long-term morbidities such as cerebral palsy and developmental delay.

But a recent report by PIPARI study collaborators suggests that clinical choioamnionitis does not have a major independent role in the pathogenesis of neurodevelopmental problems in very preterm infants. The authors argue that rather than choioamnionitis other underlying pathologies behind preterm delivery may be contributory to preterm brain injury.

A recent report from the EPIPAGE2 collaborators contrasts our findings and suggests that among neonates born between 24 and 34 weeks’ gestation, in-hospital mortality due to PPROM was not statistically significant.
But neonates with fetal growth restriction had higher mortality risk (adjusted OR 3.0, 95% CI 1.9 to 4.7) than those born after preterm labour. There are also those who propose that SGA and preterm birth comprise a double-hit injury highly predisposing to increased mortality and CLD. In our study, SGA was an independent risk factor for increased mortality/CLD.

With improving survival, we need to focus on reducing the serious morbidities in these infants and our current obstetric and neonatal practices need to be reviewed in achieving these goals. We do not have the data on type and duration of maternal antibiotics used. Maternal antibiotic therapy has shown to prolong the latency of pregnancy, reduce FIRS and thereby reduce the morbidities, but it remains unclear which antibiotic regime is better to achieve these results. The focus may still need to be on the antenatal interventions to reduce the fetal inflammatory response.

We acknowledge the limitations of the study. The cohort is confined to NICU admissions and did not report on stillbirths, terminations of pregnancy and neonatal deaths prior to NICU admission. Long-term outcome data are also not available for this cohort. However, the main strengths are a large cohort from a well-defined geographic region and prospectively collected comprehensive data outcomes.

In conclusion, neonates with a history of PPROM prior to 24 weeks’ gestation have worse outcomes when compared with Late-PPROM or No-PPROM. Clinicians should focus on interventions to prolong the latency and reduce the fetal inflammatory response.

Acknowledgements The authors thank the directors, the NICUS members and the audit officers of all tertiary units in supporting this collaborative study: NICUS, Dr Jennifer Bowen (chairperson), Barbara Bajuk (coordinator), Sara Sedgley (research officer); Canberra Hospital, Dr Hazel Carlisle (director), Judith Smith; John Hunter Children’s Hospital, Dr Paul Craven (director), Lynne Cruden, Alissia Argomand; Royal Prince Alfred Hospital, Ingrid Rieger (director), Dr Girvan Malcolm, Tracey Lutz (clinical director), Shelley Reid; Liverpool Hospital, Dr Jacqueline Stack (director), Dr Ian Callander, Kathryn Medlin, Kaye Marcini; Nepean Hospital, Dr Vijay Shingde, Mee Fong Chiu, Kerrie Bonzer; The Children’s Hospital at Westmead, Professor Nadia Badawi (director), Dr Robert Halliday, Caroline Karskens; Royal North Shore Hospital, Dr Mary Paradisis (director), Associate Professor Martin Kluckow, Claire Jacobs, Sydney Children’s Hospital, Dr Andrew Numa (director), Dr Gary Williams, Janelle Young; Westmead Hospital, Dr Melissa Luig (director), Jane Baird; and Royal Hospital for Women, Associate Professor Kei Lui (director), Dr Juliee Oel, Diane Cameron. We also thank the babies and their families, the nursing and midwifery, obstetric and medical records staff of the obstetric and children’s hospitals in NSW and the ACT.

Contributors PP conceptualised and designed the study, analysed and interpreted the data, and drafted the initial manuscript. ALM and KL contributed to the initial concept and design of the study, analysis and interpretation of data. BB designed the data collection instruments, coordinated and supervised data collection, and critically reviewed the manuscript. SB conceptualised and designed the study, coordinated and supervised data analyses and manuscript write-up, and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

Competing interests None declared.

Ethics approval South Eastern Sydney and Illawarra Area Health Service Human Research Ethics Committee-Northern Sector.

Provenance and peer review Not commissioned; externally peer reviewed.

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