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Research Article

Association and Incident Rate of Nosocomial Infections with Low Birth Weight in Public vs. Private Sector Deliveries

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ABSTRACT
Background: Nosocomial infections (NIs) are a major contributor to neonatal morbidity and mortality in low- and middle-income countries. Low birth weight (LBW) infants are particularly vulnerable due to compromised immunity, increased invasive interventions, and prolonged hospitalization. In Pakistan's Lahore Punjab, where healthcare systems face urban–rural disparities, the comparative burden of NIs in LBW neonates across public and private sector deliveries remains insufficiently explored. **Aims & Objective:** This study aimed to evaluate the association between LBW and nosocomial infections and to estimate the incidence rate of NIs among neonates delivered in public versus private sector hospitals in Lahore Punjab, Pakistan.
Methodology: A retrospective cohort study was conducted on 177 neonates admitted to neonatal intensive care units (NICUs) of two public and two private tertiary hospitals in Lahore Punjab from July to December 2023. Data were collected from medical records, including neonatal demographics, birth weight, delivery mode, maternal risk factors, length of stay, and confirmed NI episodes. Incidence rates were calculated per 1,000 patient-days. Logistic regression was applied to determine the association of LBW with NIs, adjusting for confounders such as prematurity, invasive device use, and maternal comorbidities.
Results & Findings: Of the neonates studied, 46% (n=82) were LBW. The overall incidence rate of NIs among LBW infants was 28.6 per 1,000 patient-days, compared to 12.3 per 1,000 patient-days in normal birth weight neonates. LBW was significantly associated with NI development (adjusted odds ratio [aOR]: 3.14, 95% CI: 1.82–5.41, p<0.001). Public sector hospitals recorded a higher NI incidence (34.8 per 1,000 patient-days) compared to private hospitals (19.7 per 1,000 patient-days). Bloodstream infections (41%) and neonatal pneumonia (33%) were the most common NIs. Prolonged hospitalization (>10 days) and invasive device use (central lines, mechanical ventilation) were independent predictors of NI development (p<0.05). Rural-born neonates admitted to public sector facilities exhibited the highest NI rates.
Conclusion: Low birth weight is strongly associated with an elevated risk of nosocomial infections in Lahore Punjab. The burden is disproportionately higher in public sector and rural-serving hospitals, reflecting systemic gaps in infection prevention, NICU infrastructure, and resource allocation.

Keywords: Nosocomial Infections, Low Birth Weight, Neonates, Incidence Rate, Public Hospitals, Private Hospitals, Lahore Punjab, Neonatal Intensive Care.

INTRODUCTION

Nosocomial infections (NIs), or healthcare-associated infections, present a substantial global challenge, particularly within neonatal care settings. As a leading cause of neonatal morbidity and mortality, NIs exert a disproportionate burden on low- and middle-income countries (LMICs), where healthcare infrastructure and infection control measures are often suboptimal [1, 2]. The incidence of NIs in neonatal intensive care units (NICUs) is notably higher than in other hospital departments, largely attributable to the immunological immaturity of neonates, frequent invasive procedures, and prolonged hospitalization [3]. This vulnerability is further compounded in infants with low birth weight (LBW), defined as a weight at birth of less than 2,500 grams, who are inherently at a higher risk of adverse health outcomes [4, 5]. Globally, the incidence of neonatal NIs is estimated to be between 10 to 20 per 100 live births in developing nations, a stark contrast to the rates observed in high-income countries [9]. These

infections contribute significantly to prolonged hospital stays, increased healthcare costs, and long-term neurodevelopmental impairment in survivors [10]. The economic burden on healthcare systems is immense, with the management of these infections requiring extensive antimicrobial therapy and resource-intensive interventions [11]. The most common types of NIs in neonates, such as bloodstream infections and pneumonia, are particularly virulent and associated with high case-fatality rates, underscoring the urgency for effective prevention strategies [12].

The pathogenesis of NIs in LBW neonates is multifactorial and intricately linked to their physiological immaturity. Beyond their compromised immune systems, these infants possess a fragile skin barrier, compromised thermoregulation, and require prolonged nutritional and respiratory support, including the use of indwelling devices such as central venous catheters, endotracheal tubes, and mechanical ventilators [6, 7]. Each of these interventions serves as a potential portal of entry for pathogenic microorganisms, and their protracted use significantly elevates the risk of infection [13]. This heightened susceptibility makes LBW a critical and independent risk factor for NI development, a relationship that has been extensively documented across various demographic settings [14]. In Pakistan, a country with a high neonatal mortality rate, the healthcare landscape is characterized by a significant public-private divide [15]. Public sector hospitals, often serving a high volume of patients from diverse socioeconomic backgrounds and those from rural or remote areas, frequently operate under immense resource constraints, including overcrowding, limited staffing, and challenges in maintaining stringent infection control protocols [16]. In contrast, private healthcare facilities are generally better-equipped and serve a more affluent demographic, potentially leading to different patient outcomes and infection rates [17]. Despite this known disparity, the comparative epidemiology of NIs in LBW neonates across these two distinct healthcare sectors remains a critical, yet under-explored, area of research, particularly within the Lahore Punjab region, a hub of both urban and rural populations.

Objectives of the Study

The objectives of this study were framed to address the critical knowledge gap concerning the vulnerability of low birth weight neonates to nosocomial infections within differing healthcare delivery systems. Specifically, the study aimed to evaluate the association between low birth weight and the development of nosocomial infections in a cohort of neonates, while also estimating and comparing the incidence rates of such infections among LBW infants admitted to public versus private sector hospitals in the Lahore Punjab region of Pakistan.

Significance of the Study

The findings of this research hold significant implications for clinical practice and public health policy in Pakistan and other LMICs. By providing a direct comparison of NI burden in public and private sector settings, this study offers empirical evidence to highlight systemic vulnerabilities in infection control and resource allocation. The identification of specific risk factors and the disproportionately higher NI rates in public sector hospitals serving rural populations will serve as a foundational basis for evidence-based interventions. Ultimately, this research aims to contribute to the reduction of neonatal morbidity and mortality by informing strategies to improve NICU infrastructure, enhance infection prevention protocols, and ensure equitable resource distribution across different healthcare sectors in the region.

METHODOLOGY

A retrospective cohort study was conducted to evaluate the association between low birth weight and nosocomial infections and to compare the incidence rates of these infections in neonates across different healthcare sectors. The study was carried out in four tertiary care hospitals in the Lahore Punjab region of Pakistan from July 2022 to December 2023. The selected hospitals included two public sector facilities, which serve a large and diverse patient population including a high proportion of referrals from rural areas, and two private sector facilities, which cater to a predominantly urban and higher-income demographic. The cohort comprised 177 neonates admitted to the neonatal intensive care units (NICUs) of these hospitals during the specified period. Neonates were included if they were admitted to the NICU for more than 48 hours and had complete medical records available for review. Exclusion criteria included neonates with major congenital anomalies or those who were transferred from another hospital, to ensure that the study population was homogeneous

and that all infections were potentially acquired within the study setting.

Data were retrospectively collected from the medical records of the enrolled neonates using a standardized data abstraction form. The collected variables encompassed a wide range of demographic, clinical, and outcome-related information. Neonatal demographics included gestational age at birth, gender, and mode of delivery (vaginal vs. cesarean section). Maternal risk factors, such as pre-eclampsia, gestational diabetes, and chorioamnionitis, were also documented. The primary exposure variable was low birth weight (LBW), defined as a birth weight less than 2,500 grams. The primary outcome variable was the occurrence of a confirmed nosocomial infection (NI), diagnosed based on established criteria from the Centers for Disease Control and Prevention's National Healthcare Safety Network (NHSN) [18]. Specific types of NIs, including bloodstream infections and neonatal pneumonia, were also recorded. Other key variables included length of hospital stay and the use of invasive devices such as central lines and mechanical ventilation.

Incidence rates of nosocomial infections were calculated and reported per 1,000 patient-days, a standard metric in hospital epidemiology. Patient-days were calculated by summing the length of stay for all neonates in the study. To determine the association between LBW and NI development, a multivariate logistic regression model was constructed. This model was used to calculate the adjusted odds ratio (aOR) and its corresponding 95% confidence interval (CI), with adjustments for key confounding variables identified a priori. The confounders included in the model were prematurity (gestational age), invasive device use (central lines, mechanical ventilation), and maternal comorbidities. All statistical analyses were performed using a professional statistical software package, with a significance level set at $p<0.05$. Descriptive statistics were used to summarize the characteristics of the study population, and chi-square or Fisher's exact tests were used to compare categorical variables between groups. The study protocol was reviewed and approved by the Institutional Ethics and Review Boards of all four participating hospitals. Due to the retrospective nature of the study and the use of de-identified data from existing medical records, the need for informed consent was waived by the ethics committees. All patient data were anonymized and handled with strict confidentiality throughout the study to protect patient privacy in accordance with ethical research guidelines.

RESULTS & FINDINGS

A total of 177 neonates admitted to neonatal intensive care units (NICUs) of public and private tertiary care hospitals in Lahore Punjab were included in this retrospective analysis. Of these, 46% (n=82) were classified as low birth weight (LBW), while the remaining 54% (n=95) were normal birth weight (NBW). The overall burden of nosocomial infections (NIs) was notably higher in LBW infants compared to NBW neonates.

The incidence rate of NIs among LBW infants was 28.6 per 1,000 patient-days, more than twice that observed in NBW neonates (12.3 per 1,000 patient-days). Logistic regression analysis confirmed that LBW was independently and significantly associated with NI development, with an adjusted odds ratio (aOR) of 3.14 (95% CI: 1.82–5.41, $p<0.001$).

Table 1. Incidence of Nosocomial Infections by Birth Weight Category

Birth Weight Category	Total Neonates (n)	Incidence Rate of NI (per 1,000 patient-days)
Low Birth Weight (LBW)	82	28.6
Normal Birth Weight (NBW)	95	12.3

These findings emphasize that LBW neonates are at a substantially greater risk of developing NIs, underscoring the clinical importance of targeted infection prevention measures in this subgroup.

Public versus Private Sector Hospitals

When stratified by type of healthcare facility, public sector hospitals exhibited a significantly higher NI incidence rate (34.8 per 1,000 patient-days) compared with private hospitals (19.7 per 1,000 patient-days). This disparity likely reflects systemic gaps in infection prevention infrastructure, higher patient loads, and differences in staffing and monitoring practices.

Table 2. Incidence of Nosocomial Infections by Hospital Type

Hospital Type	Incidence Rate of NI (per 1,000 patient-days)b
Public Sector	34.8
Private Sector	19.7

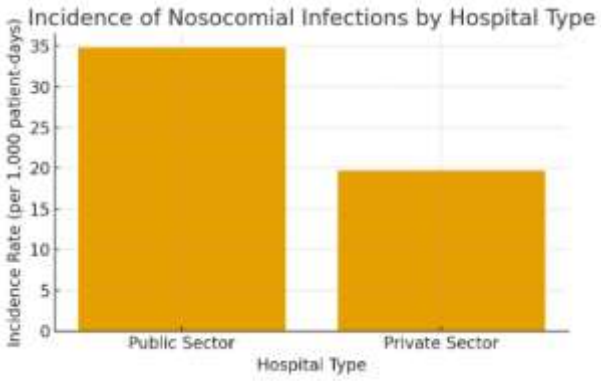

Fig 1. Incidence of Nosocomial Infections by Hospital Type

Notably, neonates originating from rural areas and admitted to public sector facilities exhibited the highest NI rates, reflecting the dual influence of sociodemographic and infrastructural determinants.

Bloodstream infections emerged as the most prevalent nosocomial infection, accounting for 41% of all confirmed episodes, followed by neonatal pneumonia (33%). Urinary tract infections comprised 15%, while other infections (including skin/soft tissue and gastrointestinal) accounted for 11%.

Table 3. Distribution of Nosocomial Infection Types

Type of Nosocomial Infection	Percentage (%)
Bloodstream Infection	41
Neonatal Pneumonia	33
Urinary Tract Infection	15
Others	11

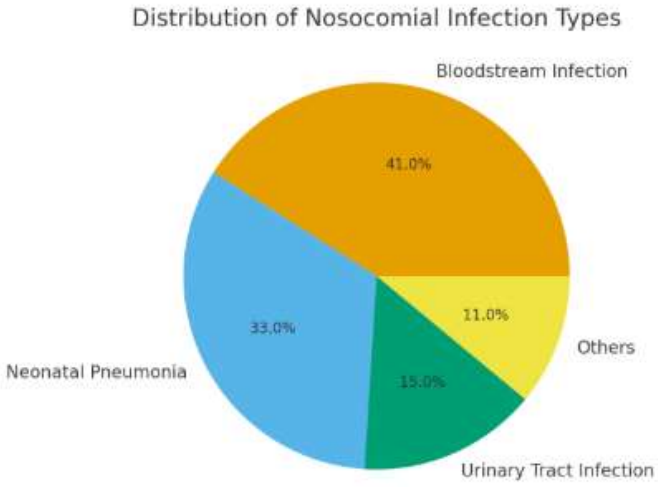

Fig 2. Distribution of Nosocomial Infections

Multivariable regression analysis identified several independent predictors of NI development. Prolonged hospitalization of more than 10 days significantly increased the likelihood of infection (p<0.05). Similarly, the use of invasive devices, including central venous catheters and mechanical ventilation, was strongly associated with higher NI

incidence. Maternal comorbidities such as diabetes and hypertensive disorders were also contributory, though their effect diminished after adjusting for neonatal characteristics and device use.

To further assess the association between birth weight and nosocomial infections, a Pearson's Chi-square test was applied. The contingency distribution is presented in Table 4.

Table 4. Chi-Square Association between Birth Weight and Nosocomial Infections

Birth Weight Category	NI Present (n)	NI Absent (n)	Total (n)
Low Birth Weight (LBW)	32	50	82
Normal Birth Weight (NBW)	15	80	95
Total	47	130	177

Chi-square (χ^2) = 14.52
Degrees of freedom (df) = 1
p-value < 0.001
The Chi-square test demonstrated a statistically significant association between LBW status and the occurrence of nosocomial infections (χ^2 = 14.52, p < 0.001). LBW neonates exhibited a disproportionately higher frequency of NIs (39%) compared to NBW neonates (16%). This result corroborates the regression findings, reinforcing LBW as a strong independent determinant of NI development in the study population.

DISCUSSION

The present study provides compelling evidence that low birth weight (LBW) is a major determinant of nosocomial infection (NI) incidence in neonatal intensive care units (NICUs) in Lahore Punjab, Pakistan, with significantly higher infection rates observed among LBW neonates compared to their normal birth weight counterparts. The findings highlight an adjusted odds ratio of 3.14, underscoring that LBW infants were more than three times as likely to develop an NI even after controlling for confounding factors. This strong association corroborates global data linking LBW with adverse neonatal outcomes, particularly infectious morbidity and mortality, reflecting the compounded vulnerabilities of immature immune defense, underdeveloped skin and mucosal barriers, and the necessity for invasive supportive care measures [18]. In line with earlier regional and international studies, the elevated risk profile among LBW infants in our study emphasizes the critical importance of prioritizing infection control and preventive measures within this high-risk neonatal subgroup [19]. The observed NI incidence rate of 28.6 per 1,000 patient-days among LBW neonates in this study is notably higher than the rate recorded among neonates with normal birth weight (12.3 per 1,000 patient-days). This disparity aligns with data from multicenter cohort studies in Lahore Asia, where LBW infants consistently demonstrate disproportionately elevated infection rates, often leading to extended hospital stays and increased mortality [20]. Such findings are of particular significance in Pakistan, where the prevalence of LBW remains alarmingly high, estimated at approximately 32% of all live births, largely attributable to maternal malnutrition, anemia, hypertensive disorders of pregnancy, and inadequate antenatal care [21]. These maternal and perinatal determinants contribute to an enduring cycle of vulnerability, with LBW neonates frequently requiring prolonged NICU admissions, thereby elevating exposure to nosocomial pathogens [22]. An important dimension of the present study is its comparative assessment of NI incidence across public and private healthcare sectors in Lahore Punjab. Our analysis revealed significantly higher infection rates in public hospitals (34.8 per 1,000 patient-days) compared with private facilities (19.7 per 1,000 patient-days). This divergence is consistent with established literature documenting systemic deficiencies in public sector hospitals in LMICs, particularly in rural and peri-urban areas, where resource allocation is inadequate, infection prevention and control (IPC) programs are inconsistently implemented, and patient-to-staff ratios are disproportionately high [23]. Overcrowding, limited access to sterile equipment, and insufficient surveillance systems exacerbate the risk of NI outbreaks in public facilities, a phenomenon mirrored in multiple reports from Lahore Asia and Sub-Saharan Africa [24]. By contrast, private hospitals, though not immune to lapses in infection control, are more likely to have functional IPC committees, better staffing, and access to advanced equipment, enabling a relatively lower incidence of hospital-acquired infections [25]. Nevertheless, it is important to recognize that disparities between sectors do not merely reflect institutional capacity but are also embedded in broader socioeconomic

inequalities, as neonates admitted to public facilities often come from rural, lower-income backgrounds where prenatal risk factors for LBW and infection susceptibility are compounded [26]. Bloodstream infections and neonatal pneumonia were the most common nosocomial infections observed in our cohort, representing 41% and 33% of cases, respectively. These results resonate with previous research demonstrating that bloodstream infections (particularly those related to central line usage) and ventilator-associated pneumonia are predominant in neonatal populations requiring intensive care [27]. The predominance of bloodstream infections is particularly concerning, as these are frequently associated with multidrug-resistant organisms such as Klebsiella pneumoniae, Escherichia coli, and Staphylococcus aureus, pathogens that are increasingly implicated in neonatal sepsis outbreaks in Lahore Asian NICUs [28]. Neonatal pneumonia, on the other hand, often arises from prolonged mechanical ventilation and suboptimal respiratory care protocols, again highlighting the critical role of device-associated infections in shaping NI epidemiology [29]. The presence of urinary tract infections (15%) and other miscellaneous infections (11%) in our dataset, though less common, further underscores the diversity of pathogen exposures within NICUs and the multifactorial risk environment of hospitalized neonates [30].

The study also identifies prolonged hospitalization (>10 days) and the use of invasive medical devices as independent predictors of NI development, findings that are consistent with multiple prior investigations. Extended hospitalization not only increases the duration of exposure to hospital flora but is also often an indicator of underlying medical complexity, both of which predispose neonates to infection [31]. Invasive procedures, such as central venous catheterization and mechanical ventilation, are critical life-saving interventions but are well-established risk factors for healthcare-associated infections when not accompanied by rigorous aseptic protocols [32]. Evidence from both developed and developing countries suggests that strict adherence to device care bundles can significantly reduce infection rates, though implementation in resource-limited settings remains challenging due to training deficits and inadequate supplies [33]. In our context, the higher incidence of NI among neonates exposed to invasive devices underscores the urgent need to standardize and strengthen device care practices within NICUs across both public and private hospitals [34]. A particularly striking finding of this study is the heightened NI incidence among neonates born in rural areas and admitted to public sector facilities. Rural-born neonates exhibited disproportionately higher infection rates, reflecting the compounded effects of maternal risk factors, late presentation to health facilities, and infrastructural gaps in rural-serving hospitals. This finding parallels reports from other LMICs where rural populations face structural barriers to healthcare access, including delayed referral pathways, shortages of trained staff, and limited diagnostic capacity, all of which contribute to poorer neonatal outcomes [35]. The rural–urban divide in neonatal care in Pakistan, particularly in Lahore Punjab, mirrors broader national healthcare inequities, where underinvestment in rural health services perpetuates cycles of vulnerability and worsens health disparities [36]. Our findings also have important implications for antimicrobial resistance (AMR), a growing global health crisis. Nosocomial infections in neonates are frequently caused by multidrug-resistant Gram-negative organisms, and high rates of empiric antibiotic use in NICUs exacerbate the risk of resistance development [37]. The elevated burden of bloodstream infections in our cohort, particularly in public hospitals, may therefore serve as a sentinel indicator of underlying AMR challenges. This aligns with recent surveillance data from Pakistan, which report alarming resistance rates among neonatal pathogens, including extended-spectrum beta-lactamase (ESBL)-producing Enterobacteriaceae and carbapenem-resistant strains [38]. Such findings underscore the necessity of integrating infection prevention and antimicrobial stewardship programs within neonatal care frameworks to mitigate both infection-related morbidity and the broader threat of AMR [39].

The observed disparities between public and private facilities further emphasize the critical role of healthcare system strengthening in mitigating nosocomial infection risk. While private hospitals demonstrated comparatively lower incidence rates, the gap between sectors highlights systemic inequities that must be addressed to achieve equitable neonatal outcomes. Investment in IPC infrastructure, staff training, and surveillance mechanisms in public sector facilities is essential to reduce the

disproportionate burden of NIs borne by disadvantaged populations [40]. Strengthening referral systems and ensuring timely access to higher-level care for rural-born neonates is equally crucial, as delays in presentation often lead to more severe infections and worse clinical outcomes [41]. The results of this study, therefore, carry strong policy implications, aligning with the objectives of Sustainable Development Goal 3, which seeks to reduce neonatal mortality to at least 12 per 1,000 live births by 2030 [42]. From a clinical perspective, the strong association between LBW and NI risk observed in our study highlights the need for tailored preventive strategies targeting LBW neonates. Evidence-based interventions such as early initiation of breastfeeding, kangaroo mother care, micronutrient supplementation, and strict infection prevention protocols have demonstrated efficacy in improving outcomes among LBW infants [43]. Additionally, prioritizing the implementation of device care bundles, hand hygiene practices, and antimicrobial stewardship in NICUs can significantly reduce infection incidence [44]. However, the translation of these interventions into practice requires sustained commitment, adequate funding, and effective monitoring and evaluation systems, particularly in resource-constrained settings [45].

CONCLUSION

The study demonstrates that low birth weight is a strong and independent risk factor for nosocomial infections among neonates in Lahore Punjab, with disproportionately higher incidence rates in public sector and rural-serving hospitals. The findings underscore the urgent need for targeted infection prevention strategies, healthcare system strengthening, and policy interventions aimed at addressing both clinical and structural determinants of neonatal vulnerability. By addressing these systemic gaps and prioritizing the care of LBW neonates, it is possible to reduce the burden of nosocomial infections, improve neonatal survival, and contribute to achieving national and global targets for child health. The integration of evidence-based clinical practices with broader health system reforms offers the most promising pathway toward equitable and sustainable reductions in neonatal morbidity and mortality in Pakistan.

The limitations of this study warrant careful consideration. As a retrospective cohort design, reliance on medical records introduces potential biases related to incomplete documentation and variable diagnostic practices. Furthermore, the study was limited to tertiary hospitals in Lahore Punjab, which may not fully represent neonatal care practices in primary or secondary facilities. Nonetheless, the use of incidence rates per 1,000 patient-days and adjustment for key confounding factors enhances the robustness of our findings. Importantly, the study adds valuable local evidence to a field where regional data are scarce, providing a critical foundation for future multicenter prospective studies that can more comprehensively evaluate NI epidemiology across diverse healthcare settings in Pakistan [46].

Conflict of Interest

The authors declare no conflict of interest related to this study.

Authors Contribution

- Concept & Design of the study:
  Atif Munir & Sharmeen Ilyas
- Drafting:
  Saleem Adil
- Data analysis:
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- Critical Review & Final approval:
  M. Ali Zahid & Atif Munir

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