

## Clinical Profile, Risk Factors and Surgical Outcomes of Neonatal Emergencies: A Retrospective Observational Cohort Study from a Tertiary Care Hospital

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### ABSTRACT

**Background:** Neonatal surgical emergencies remain among the most demanding problems in paediatric surgical practice. Survival in high-income settings now routinely exceeds ninety per cent for most index conditions, yet reported mortality from tertiary centres in South Asia continues to sit between fifteen and forty per cent. Observational data from such centres suggest that this gap is driven less by the operation itself than by everything that surrounds it: late recognition, unstabilised transport, sepsis acquired before the neonate ever reaches a surgeon, and constrained neonatal intensive care capacity.

#### Objectives

To describe, through observation of a consecutive clinical cohort, the demographic and clinical profile of neonates undergoing emergency surgery at a tertiary referral hospital; to quantify the spectrum of diagnoses and their case fatality; and to identify, by statistical association rather than experimental manipulation, independent perinatal, referral-related and intraoperative correlates of in-hospital mortality.

**Methods:** This was a retrospective, single-centre, purely observational cohort study. No intervention of any kind was introduced, withheld, or altered by the investigators; every neonate received whatever care was clinically indicated by the treating team, entirely independent of, and prior to, this research. We reviewed case records, operation notes, anaesthetic charts and neonatal intensive care unit flow sheets for all neonates aged twenty-eight days or less who underwent emergency surgical treatment between January 2021 and December 2023, against a pre-piloted proforma. The primary outcome was in-hospital mortality; secondary outcomes were major postoperative morbidity graded by the Clavien–Dindo classification, duration of mechanical ventilation and length of stay. Variables associated with mortality at a significance threshold of  $p < 0.10$  on univariate testing were entered into a multivariable logistic regression model to identify independent statistical correlates; model discrimination was assessed by the area under the receiver operating characteristic curve. As an observational design, this study can identify association, not causation.

**Results:** Of 412 neonatal admissions screened, 174 operated neonates formed the analytic cohort. The male-to-female ratio was 1.9:1, median gestational age was 37 weeks (interquartile range 34–38) and median birth weight was 2,480 g (interquartile range 2,050–2,840). Anorectal malformation (23.6%), congenital intestinal obstruction (18.4%) and oesophageal atresia with tracheo-oesophageal fistula (14.4%) accounted for more than half of all admissions. Overall in-hospital mortality was 25.3% (44 of 174). Case fatality was highest for congenital diaphragmatic hernia (47.1%), necrotising enterocolitis (42.9%) and oesophageal atresia (36.0%). On multivariable analysis, inotrope requirement (adjusted odds ratio 5.02, 95% CI 1.97–12.79), pre-operative sepsis (aOR 4.56, 95% CI 1.93–10.78), birth weight below 1,500 g (aOR 3.82, 95% CI 1.42–10.27), intraoperative bowel perforation (aOR 3.14, 95% CI 1.28–7.71) and referral delay exceeding forty-eight hours (aOR 2.87, 95% CI 1.21–6.81) were independently associated with death after adjustment for one another. The model achieved an area under the curve of 0.86.

**Conclusions:** In this observational cohort, mortality after neonatal emergency surgery was more strongly associated with

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pre-operative physiological state than with the anatomical diagnosis alone. Four of the five independent correlates identified describe features that are, in principle, modifiable earlier antenatal detection, structured referral pathways, protocol-driven transport and pre-operative stabilisation but because this was a non-interventional study, it cannot demonstrate that modifying them would causally reduce mortality; it can only identify them as priority targets for future prospective or interventional evaluation. The strength and consistency of the association between the pre-operative interval and mortality suggest that this interval, rather than further refinement of operative technique, is where such future interventional research would be best directed.

**Keywords:** neonatal surgery; surgical emergency; congenital anomaly; observational cohort study; risk factors; in-hospital mortality; Clavien–Dindo classification; referral delay; tertiary care; low- and middle-income countries

## INTRODUCTION

### The clinical problem

Roughly one newborn in every thirty-three is born with a structural congenital anomaly, and a substantial minority of these anomalies demand surgical correction within the first hours or days of life. The neonatal surgical emergency is a distinct clinical entity: the patient is physiologically immature, thermally labile, metabolically brittle, and often presents after a period of unrecognised deterioration. Unlike the older child, the neonate has little functional reserve with which to absorb the combined insult of an underlying anomaly, an anaesthetic and a laparotomy or thoracotomy.

The conditions themselves are familiar to any paediatric surgical unit: anorectal malformation, oesophageal atresia with or without a tracheo-oesophageal fistula, congenital diaphragmatic hernia, intestinal atresias, malrotation with midgut volvulus, Hirschsprung disease presenting as neonatal obstruction, necrotising enterocolitis with perforation, and the abdominal wall defects. What varies dramatically between settings is not the anatomy but the outcome. Survival figures published from specialist centres in Western Europe, North America and East Asia now approach or exceed ninety per cent for most of these diagnoses. Series from tertiary hospitals in South Asia and sub-Saharan Africa continue to report mortality anywhere between fifteen and forty-five per cent.

That gap is uncomfortable, and observational data of this kind suggest it is not primarily a gap in operative skill. The technical steps of a Duhamel pull-through or a primary oesophageal anastomosis are taught and performed competently in high-volume units across the subcontinent. The gap appears, instead, to correlate with the surrounding infrastructure: antenatal ultrasonography that is not universally available or not systematically interpreted; deliveries conducted far from a surgical centre; transport undertaken in a private vehicle without warmth, oxygen or intravenous access; and, at the receiving end, a finite number of neonatal ventilators shared between medical and surgical neonates.

### Why the pre-operative interval matters

A recurring observation in the literature, and one that motivated the present study, is that outcome correlates more strongly with the neonate's physiological condition at the moment of induction than with the complexity of the reconstruction that follows. A neonate with a jejunal atresia who arrives warm, euglycaemic, decompressed and adequately resuscitated within twelve hours of the first bilious vomit tends, on observational grounds, to have a better prognosis. The same neonate, arriving on the fourth day with established sepsis, hypovolaemia and an ischaemic bowel segment, tends to have a markedly worse one despite an identical operation.

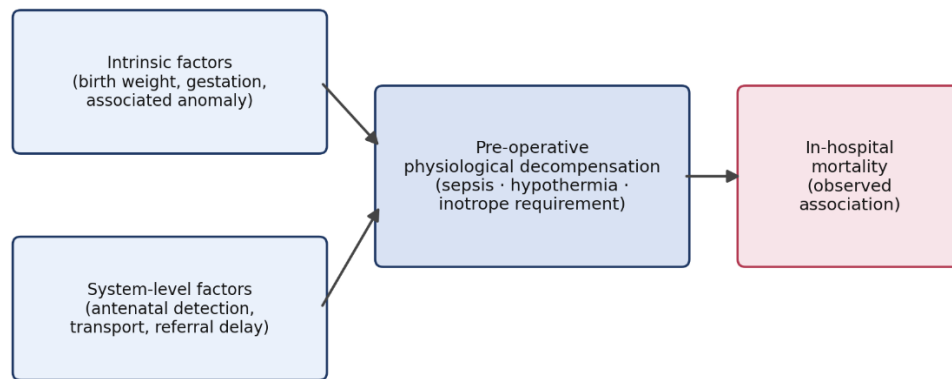
This association matters because it points to where the therapeutic opportunity may lie, even though this observational study cannot itself confirm that opportunity by experiment. If mortality were associated chiefly with the intrinsic severity of the malformation, improvement would most plausibly depend on advances in surgical technique or neonatal intensive care technology. If, as the data below suggest, it is instead associated with delay, hypothermia and sepsis acquired before admission, then the hypothesis worth testing prospectively is that referral pathways, transport protocols and stabilisation checklists interventions that are considerably cheaper and faster to implement could improve outcomes. That hypothesis is generated by, but not proven by, the present analysis.

### Rationale and knowledge gap

Several Indian series have described the spectrum of neonatal surgical disease, and a smaller number have reported crude mortality by diagnosis. Fewer have attempted a multivariable analysis that disentangles the contribution of birth weight, gestation, referral interval, sepsis and intraoperative findings while adjusting for one another. Without such adjustment it is difficult to know whether, for example, the apparent association of prematurity with death is direct, or whether it is largely mediated through low birth weight and sepsis. Practical prioritisation of scarce resources requires that distinction to be made, and requires it to be made honestly, within the limits of what an observational design can support.

The present study was therefore designed to characterise, in a consecutive three-year observational cohort from a single tertiary referral centre, the clinical profile of neonates undergoing emergency surgery; to describe the outcomes achieved; and to identify which factors are independently associated with death once the others are accounted for statistically. The intention throughout was to generate specific, testable hypotheses about the pathway of care, rather than to claim, from

observational data alone, that any particular change in practice would cause an improvement in survival that claim would require a prospective or interventional study, which this is not.



*Descriptive framework only — arrows denote observed statistical association in this cohort, not a causal pathway confirmed by experiment.*

**Figure 1. Conceptual framework for the correlates of outcome in neonatal surgical emergencies, as observed in this cohort. Intrinsic and system-level factors converge on a common pathway of physiological decompensation, identified here as the principal association with outcome prior to operation. The framework is descriptive of observed associations and does not, on its own, establish causal mechanism.**

## REVIEW OF THE LITERATURE

### Global burden and the survival gradient

The Global Initiative for Children's Surgery and successive Lancet Commission analyses have repeatedly emphasised that access to safe surgical care for children is inequitably distributed. Congenital anomalies now rank among the leading causes of death in the first month of life globally, having risen in relative importance as infection-related and intrapartum-related neonatal deaths have fallen. In absolute terms, the majority of neonates born with a surgically correctable anomaly live in low- and middle-income countries, and the majority of deaths from those anomalies occur there.

Comparative series illustrate the gradient vividly. Multicentre cohorts from high-income settings report operative mortality for oesophageal atresia of under five per cent in neonates without major cardiac anomalies, and survival exceeding eighty per cent for isolated congenital diaphragmatic hernia managed with a period of pre-operative stabilisation. Comparable series from tertiary hospitals across South Asia and West Africa describe mortality for the same conditions of twenty-five to fifty per cent. The 2021 multicentre observational study coordinated through the Global PaedSurg collaboration, which prospectively enrolled neonates with seven index congenital anomalies across more than two hundred centres, found that country income group remained a strong statistical correlate of death after adjustment for case mix — an association that points toward system-level factors, though, being itself observational, it does not establish which specific system change would be causally effective.

### Pattern of disease in Indian series

Indian tertiary-centre reports show a reasonably consistent disease pattern. Anorectal malformation is almost invariably the commonest single diagnosis, typically accounting for a fifth to a quarter of neonatal surgical admissions, followed by the intestinal obstructions as a group and by oesophageal atresia. Necrotising enterocolitis appears with increasing frequency in more recent series, which most authors attribute to improved survival of very preterm neonates in expanding neonatal intensive care facilities rather than to a genuine rise in incidence.

Male predominance is a near-universal finding, commonly in the region of two to one. Part of this is biological anorectal malformation and hypertrophic pyloric stenosis are genuinely commoner in males but several authors have raised the possibility that differential care-seeking for male infants also contributes. Where studies have examined sex-disaggregated referral intervals, female neonates have occasionally been found to present later, though the finding is not consistent and sample sizes are usually small; it remains an association observed in some series rather than an established effect.

### Established prognostic factors

Birth weight and gestational age

Low birth weight is the single most frequently reported correlate of death after neonatal surgery. The relationship is graded

rather than threshold-based, but most series identify a marked inflection below 1,500 g. Prematurity is associated with mortality independently in some analyses and not in others; where it loses significance, this usually occurs after adjustment for birth weight and for respiratory morbidity, suggesting that much of its association is mediated rather than direct.

#### Sepsis

Sepsis, whether present at admission or acquired subsequently, is consistently among the strongest correlates of mortality. Its interpretation is complicated by reverse causation – a perforated viscus causes sepsis, and sepsis is also a marker of delay but studies that have adjusted for the underlying diagnosis continue to find an independent statistical association. Blood culture positivity rates in Indian neonatal surgical series are frequently reported in the range of twenty to forty per cent, with a preponderance of Gram-negative organisms and a rising proportion of multidrug-resistant isolates.

#### Delay in presentation and referral

Delay has been examined using the widely cited three-delay framework originally developed for maternal mortality: delay in recognising that something is wrong, delay in reaching a facility, and delay in receiving adequate care once there. Applied to neonatal surgery, the first delay includes failure of antenatal diagnosis and failure of the birth attendant to recognise bilious vomiting, abdominal distension or an imperforate anus; the second encompasses distance, cost and the absence of an organised retrieval service; the third includes in-hospital waits for imaging, blood products, anaesthetic assessment or an available operating theatre. The framework is descriptive; it organises observed associations rather than testing them experimentally.

#### Associated anomalies and physiological scores

Major associated anomalies, particularly cardiac lesions in neonates with oesophageal atresia or anorectal malformation, are associated with substantially worse prognosis. Composite physiological scores such as SNAPPE-II have been validated as statistical predictors of mortality in surgical neonates and generally outperform any single variable, though they require arterial blood gas data that are not always obtainable in resource-constrained units.

#### Where the present study contributes

Much of the existing Indian literature is descriptive, reporting proportions and crude case fatality without formal adjustment. Where multivariable models have been constructed, they have often been limited by small sample size, by the inclusion of variables measured after the outcome had effectively been determined, or by the omission of referral-interval data. This observational study addresses those limitations by combining a reasonably sized consecutive cohort, a pre-specified variable list including a carefully defined referral interval, and a regression model constrained by an events-per-variable rule to avoid overfitting. It does not, and does not claim to, resolve the question of causal effect – that would require a subsequent prospective or interventional study of the kind proposed in Section 9.4. Aims and Objectives

#### Aim

To evaluate, by observation of a consecutive clinical cohort, the clinical profile, associated risk factors and surgical outcomes of neonates presenting with surgical emergencies to a tertiary care teaching hospital, and to identify statistical correlates of in-hospital mortality that are, in principle, amenable to future modification.

#### Primary objective

To determine the in-hospital mortality rate among neonates undergoing emergency surgical treatment, and to identify the perinatal, referral-related and intraoperative factors that are independently associated with that outcome on multivariable analysis.

#### Secondary objectives

To describe the demographic and perinatal profile of the cohort, including sex distribution, gestational age, birth weight, place of birth and mode of delivery.

To characterise the spectrum of surgical diagnoses encountered and the case fatality associated with each.

To quantify the interval between the onset of symptoms and surgical referral, and to examine its association with outcome.

To document the pattern and severity of postoperative complications using the Clavien–Dindo classification adapted for neonates.

#### Research hypothesis

Null hypothesis. In-hospital mortality among neonates undergoing emergency surgery is statistically independent of birth weight, gestational age, pre-operative sepsis, referral interval and intraoperative findings.

Alternative hypothesis. One or more of these factors is independently associated with in-hospital mortality after adjustment for the remainder. As this is an observational study, confirmation or rejection of either hypothesis describes statistical association only, and carries no direct claim of causation.

## MATERIALS AND METHODS

#### Study design and reporting standard

This was a retrospective, single-centre, purely observational cohort study; it was not an interventional or experimental study

of any kind. The investigators did not assign, withhold, standardise, trial or otherwise modify any diagnostic test, treatment, operative approach, referral pathway or transport arrangement for the purposes of this research. Every clinical decision captured in this dataset was made by the treating team according to standard institutional practice, independently of and prior to the research process, which began only after data collection was planned retrospectively. The manuscript is reported in accordance with the STROBE statement for observational research, and the corresponding checklist is provided as Appendix C. The study protocol was registered internally with the institutional research cell before data extraction commenced.

### Setting

The study was conducted in the Department of Paediatric Surgery of a tertiary care teaching hospital serving as the apex referral centre for a predominantly rural catchment of approximately eight million people. The department operates a dedicated eight-bedded neonatal surgical intensive care area within a twenty-four-bed level-III neonatal intensive care unit, with round-the-clock consultant paediatric surgical and paediatric anaesthetic cover and an on-site blood bank. Neonatal retrieval is not formally organised; the majority of referrals arrive by private transport or by general-purpose ambulance without a trained escort.

### Study period and population

All neonates admitted between 1 January 2021 and 31 December 2023 were screened. The study window was chosen to provide three complete calendar years and to include, but extend beyond, the period of pandemic-related service disruption, permitting a descriptive sensitivity comparison by year of admission.

### Inclusion criteria

Postnatal age of twenty-eight completed days or less at the time of surgical treatment.

A diagnosis requiring emergency surgical treatment, defined as an operation performed within seventy-two hours of the decision to operate, on the grounds that deferral carried a risk of death or irreversible organ loss.

Availability of a case record sufficiently complete to permit extraction of all primary and key secondary variables.

### Exclusion criteria

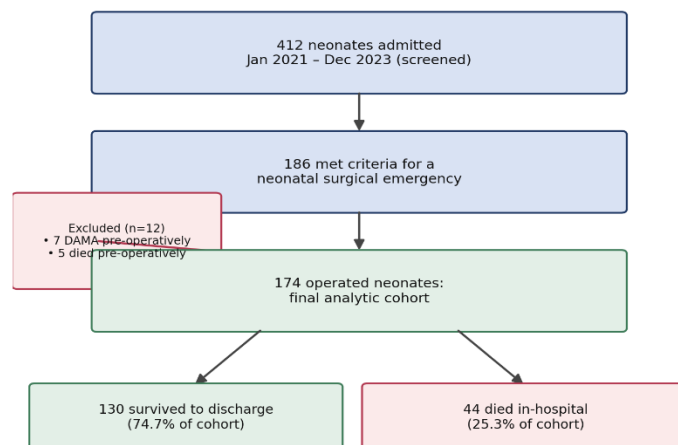
Neonates managed entirely non-operatively, including those with medical necrotising enterocolitis that resolved without surgery.

Elective or semi-elective procedures, including planned staged repairs performed beyond the emergency window.

Neonates transferred out before a definitive procedure, or discharged against medical advice pre-operatively.

Neonates who died before any operative treatment could be undertaken; these were recorded separately and are described narratively but excluded from the outcome analysis to avoid immortal-time distortion.

Case records with irrecoverable gaps in the primary outcome or in more than two of the pre-specified covariates.



*Observational, non-interventional design throughout —  
no participant was assigned to a study arm.*

**Figure 2. STROBE-compliant participant flow diagram showing screening, exclusions and the final observational analytic cohort.**

**Operational definitions**

| Term                     | Operational definition used in this study                                                                                                                                                                                                                                                     |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Neonate                  | Infant of postnatal age $\leq 28$ completed days at the time of operation.                                                                                                                                                                                                                    |
| Surgical emergency       | A condition for which operative treatment was undertaken within 72 h of the decision to operate because deferral carried a risk of death or irreversible organ loss.                                                                                                                          |
| Referral interval        | Time in hours from the first documented onset of symptoms (or from birth, for conditions apparent at birth) to arrival at this institution.                                                                                                                                                   |
| Pre-operative sepsis     | Clinical signs of systemic infection together with at least two of: total leucocyte count $< 5 \times 10^9/L$ or $> 20 \times 10^9/L$ ; C-reactive protein $> 10$ mg/L; immature-to-total neutrophil ratio $> 0.2$ ; or a positive blood culture, documented before induction of anaesthesia. |
| Hypothermia on arrival   | Axillary temperature below $36.5^\circ\text{C}$ recorded at the time of first assessment in the emergency department.                                                                                                                                                                         |
| Low birth weight         | Birth weight $< 2,500$ g; very low birth weight $< 1,500$ g.                                                                                                                                                                                                                                  |
| Prematurity              | Gestational age $< 37$ completed weeks, assessed by last menstrual period, early antenatal ultrasonography, or the New Ballard Score where neither was available.                                                                                                                             |
| Outborn                  | Delivery at any facility other than this institution, including home deliveries.                                                                                                                                                                                                              |
| Major associated anomaly | A structural anomaly in a second organ system judged to be of independent clinical significance, including haemodynamically significant cardiac lesions, and recognised syndromic associations such as VACTERL.                                                                               |
| In-hospital mortality    | Death from any cause occurring after operation and before discharge from this institution.                                                                                                                                                                                                    |
| Major morbidity          | Any postoperative complication of Clavien–Dindo grade IIIa or above.                                                                                                                                                                                                                          |

**Table 1. Operational definitions applied uniformly throughout data extraction.****Data collection**

Data were extracted from the medical records department archive, the departmental operation theatre register, anaesthetic records and neonatal intensive care unit flow charts using a structured proforma (Appendix A) that had been piloted on twenty non-study records and refined thereafter. Two investigators extracted data independently; a random ten per cent sample was cross-checked by a third investigator, and inter-rater agreement for categorical variables was assessed by Cohen's kappa, which reached 0.91. Discrepancies were resolved by consensus with reference to the source document. At no stage did data collection involve contact with, or any change to the care of, a living patient; all information was drawn from records of care that had already concluded.

Variables captured comprised demographic and perinatal details, antenatal history including whether an anomaly had been detected on antenatal ultrasonography, mode and place of delivery, referral details and interval, clinical findings at admission, laboratory and radiological investigations, pre-operative resuscitation received, operative findings and procedure performed, anaesthetic duration, postoperative course including ventilation and feeding milestones, complications graded by the Clavien–Dindo system, and final outcome.

**Outcome measures**

The primary outcome was in-hospital mortality. Secondary outcomes were major postoperative morbidity (Clavien–Dindo grade IIIa or above), duration of invasive mechanical ventilation in days, time from operation to full enteral feeding, occurrence of surgical site infection, anastomotic leak where an anastomosis had been performed, unplanned re-operation, and total length of hospital stay. All outcomes were observed as they occurred under standard care; none was influenced by the research process.

### Sample size considerations

This was a complete-enumeration study of all eligible neonates within the defined period; no a priori sample size calculation was performed, as none was required for an observational census of this kind. A post hoc assessment confirmed that 174 neonates with 44 deaths provided approximately eighty per cent power at a two-sided alpha of 0.05 to detect an odds ratio of 2.7 or greater for an exposure with a prevalence of thirty per cent. The events-per-variable ratio of 44 events to 8 candidate predictors satisfies the conventional minimum of five events per variable, though it approaches the lower bound and this is acknowledged in the limitations.

### Statistical analysis

Analyses were performed in SPSS version 26 (IBM Corp., Armonk, NY) with figures prepared in R version 4.3.1. Continuous variables were tested for normality using the Shapiro Wilk test; normally distributed variables are presented as mean with standard deviation and were compared by the independent-samples t test, while skewed variables are presented as median with interquartile range and were compared by the Mann–Whitney U test. Categorical variables are presented as frequencies with percentages and were compared using the chi-squared test, with Fisher's exact test substituted where any expected cell count fell below five.

Variables achieving  $p < 0.10$  on univariate testing, together with birth weight and gestational age retained on clinical grounds irrespective of univariate significance, were entered into a multivariable binary logistic regression model using backward stepwise elimination based on the likelihood ratio statistic. This model identifies independent statistical association, not causal effect; no causal inference framework (such as instrumental variables, propensity matching against a counterfactual exposure, or a difference-in-differences design) was applied, and none would be appropriate to a single-arm observational case series of this kind. Multicollinearity was assessed by the variance inflation factor, with a threshold of 2.5. Model calibration was evaluated by the Hosmer–Lemeshow goodness-of-fit test and discrimination by the area under the receiver operating characteristic curve. Survival to thirty days was described using Kaplan Meier estimates and compared by the log-rank test. A two-sided p value below 0.05 was regarded as statistically significant throughout.

## RESULTS

### Cohort assembly

Of 412 neonates admitted to the department during the three-year study period, 186 met the criteria for a neonatal surgical emergency. Twelve were subsequently excluded: seven were taken home against medical advice before operation, and five died during pre-operative resuscitation, leaving 174 operated neonates in the analytic cohort (Figure 2). The five pre-operative deaths are worth noting descriptively: all five arrived moribund, four had established septic shock, and the median referral interval in that small group was 96 hours.

Annual case volume was stable, with 54 neonates operated in 2021, 58 in 2022 and 62 in 2023. Observed mortality by year of admission was 27.8%, 25.9% and 22.6% respectively; the descriptive downward trend did not reach statistical significance ( $\chi^2$  for trend = 0.42,  $p = 0.517$ ), and should not be read as evidence of a causal effect of any practice change over the study period.

### Demographic and perinatal profile

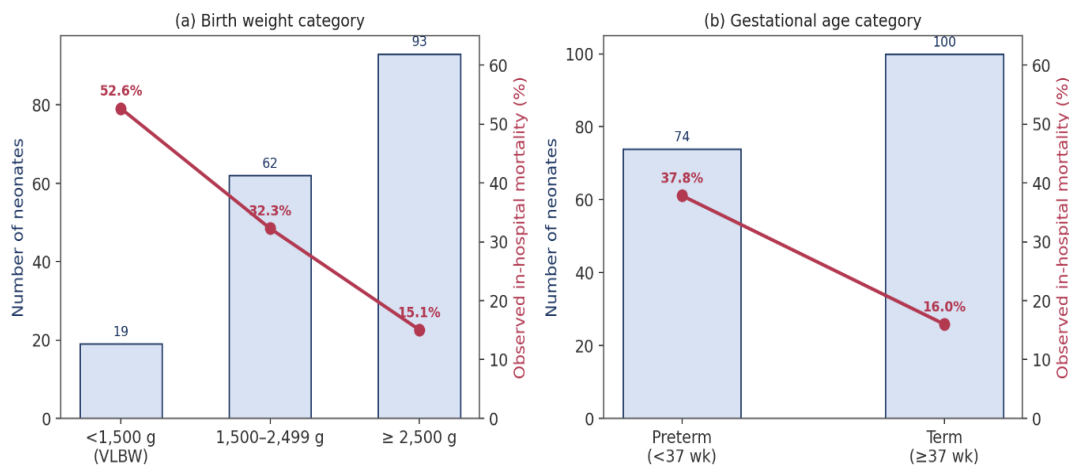
The cohort was male-predominant, with 114 males and 60 females (ratio 1.9:1). Median gestational age was 37 weeks (IQR 34–38) and median birth weight 2,480 g (IQR 2,050–2,840). Forty-two per cent were of low birth weight and 10.9% were very low birth weight. A striking 83.3% were outborn, and almost a third had been delivered at home or at a facility without any neonatal care capability. Antenatal detection of the anomaly had occurred in only 24.1% of the cohort, a figure that itself varied greatly by diagnosis from 64.7% for congenital diaphragmatic hernia to under five per cent for anorectal malformation, which is not usually visible on routine antenatal imaging.

| Characteristic                   | Total (n=174)       | Survived (n=130)    | Died (n=44)         | p value |
|----------------------------------|---------------------|---------------------|---------------------|---------|
| Male sex                         | 114 (65.5%)         | 87 (66.9%)          | 27 (61.4%)          | 0.501   |
| Female sex                       | 60 (34.5%)          | 43 (33.1%)          | 17 (38.6%)          | —       |
| Gestational age, median wk (IQR) | 37 (34–38)          | 37 (36–39)          | 35 (32–37)          | 0.003   |
| Preterm (< 37 wk)                | 74 (42.5%)          | 46 (35.4%)          | 28 (63.6%)          | 0.001   |
| Birth weight, median g (IQR)     | 2,480 (2,050–2,840) | 2,610 (2,240–2,900) | 2,050 (1,560–2,480) | < 0.001 |
| Low birth weight (< 2,500 g)     | 81 (46.6%)          | 51 (39.2%)          | 30 (68.2%)          | 0.001   |

| Characteristic                    | Total (n=174) | Survived (n=130) | Died (n=44) | p value |
|-----------------------------------|---------------|------------------|-------------|---------|
| Very low birth weight (< 1,500 g) | 19 (10.9%)    | 9 (6.9%)         | 10 (22.7%)  | 0.004   |
| Age at surgery, median d (IQR)    | 4 (2–8)       | 4 (2–7)          | 5 (2–10)    | 0.214   |
| Outborn delivery                  | 145 (83.3%)   | 104 (80.0%)      | 41 (93.2%)  | 0.043   |
| Caesarean delivery                | 67 (38.5%)    | 52 (40.0%)       | 15 (34.1%)  | 0.487   |
| Antenatal diagnosis made          | 42 (24.1%)    | 35 (26.9%)       | 7 (15.9%)   | 0.140   |
| Major associated anomaly          | 46 (26.4%)    | 28 (21.5%)       | 18 (40.9%)  | 0.011   |
| Consanguineous parentage          | 23 (13.2%)    | 16 (12.3%)       | 7 (15.9%)   | 0.545   |
| Travel distance > 100 km          | 98 (56.3%)    | 67 (51.5%)       | 31 (70.5%)  | 0.028   |

**Table 2. Baseline demographic and perinatal characteristics, stratified by observed in-hospital outcome. Values are n (%) unless otherwise stated. IQR = interquartile range. Comparisons by chi-squared, Fisher's exact or Mann–Whitney U test as appropriate.**

Figure 3. Observed mortality by birth weight and gestational age category (Table 2 data)



**Figure 3. Distribution of the cohort by (a) birth weight and (b) gestational age category, with corresponding observed in-hospital mortality shown on the secondary axis. Mortality rises steeply below 1,500 g and among preterm neonates.**

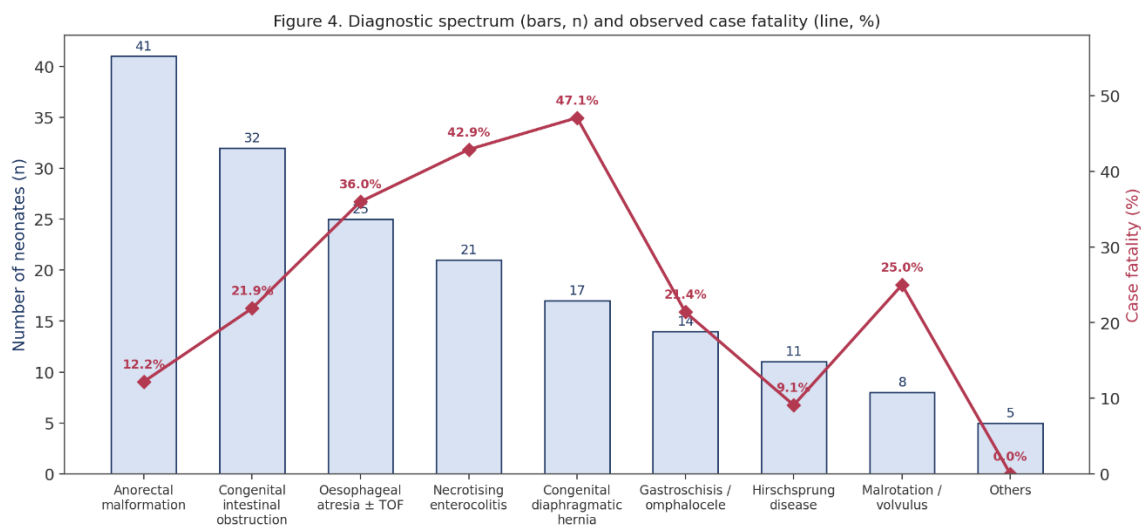
### Spectrum of diagnoses

Anorectal malformation was the single commonest diagnosis, accounting for 41 neonates (23.6%). Congenital intestinal obstruction as a group comprising duodenal atresia, jejunoileal atresia, colonic atresia and meconium ileus accounted for a further 32 (18.4%), and oesophageal atresia with tracheo-oesophageal fistula for 25 (14.4%). Together these three categories represented more than half of all admissions. Necrotising enterocolitis requiring operation accounted for 21 cases (12.1%), a proportion higher than in older Indian series and consistent, descriptively, with a growing population of surviving preterm neonates in the referring network.

Case fatality varied nearly tenfold across diagnostic categories. Congenital diaphragmatic hernia carried the highest case fatality at 47.1%, followed by necrotising enterocolitis at 42.9% and oesophageal atresia at 36.0%. At the other extreme, anorectal malformation for which the emergency procedure is usually a decompressive colostomy performed on a physiologically stable neonate carried a case fatality of 12.2%, and Hirschsprung disease presenting as neonatal obstruction only 9.1%.

| Diagnosis                            | n   | % of cohort | Deaths | Case fatality | Median stay (d) |
|--------------------------------------|-----|-------------|--------|---------------|-----------------|
| Anorectal malformation               | 41  | 23.6        | 5      | 12.2%         | 11              |
| Congenital intestinal obstruction    | 32  | 18.4        | 7      | 21.9%         | 18              |
| Duodenal atresia / web               | 11  | 6.3         | 2      | 18.2%         | 16              |
| Jejunioileal atresia                 | 14  | 8.0         | 4      | 28.6%         | 21              |
| Meconium ileus / colonic atresia     | 7   | 4.0         | 1      | 14.3%         | 17              |
| Oesophageal atresia $\pm$ TOF        | 25  | 14.4        | 9      | 36.0%         | 19              |
| Necrotising enterocolitis            | 21  | 12.1        | 9      | 42.9%         | 26              |
| Congenital diaphragmatic hernia      | 17  | 9.8         | 8      | 47.1%         | 15              |
| Gastroschisis / ruptured omphalocele | 14  | 8.0         | 3      | 21.4%         | 24              |
| Hirschsprung disease                 | 11  | 6.3         | 1      | 9.1%          | 12              |
| Malrotation with midgut volvulus     | 8   | 4.6         | 2      | 25.0%         | 20              |
| Others*                              | 5   | 2.9         | 0      | 0.0%          | 9               |
| Total                                | 174 | 100.0       | 44     | 25.3%         | 16              |

**Table 3. Spectrum of neonatal surgical emergencies with corresponding observed case fatality and median length of stay. \*Others comprised sacrococcygeal teratoma with obstructed labour sequelae (2), neonatal testicular torsion (1), incarcerated inguinal hernia (1) and spontaneous gastric perforation (1). TOF = tracheo-oesophageal fistula.**



**Figure 4. Distribution of diagnoses across the cohort (bars, n) with observed case fatality (line, %). The commonest diagnosis observed was not the most lethal.**

#### Clinical presentation and pre-operative status

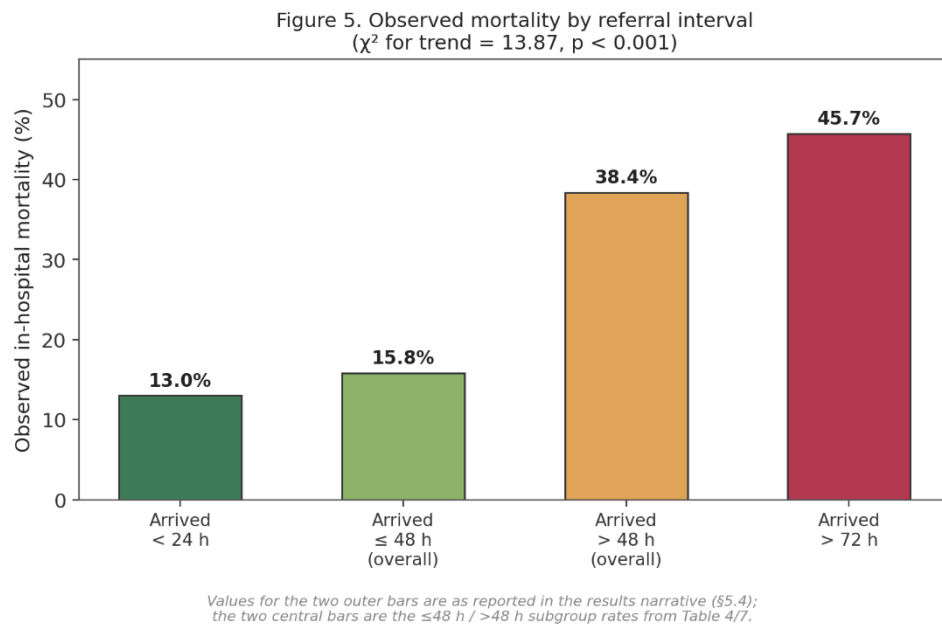
The presenting complaint reflected the underlying anatomy in most cases: abdominal distension and bilious vomiting dominated the obstructive group, while excessive frothing with choking on the first feed characterised oesophageal atresia, and respiratory distress from the first minutes of life pointed to diaphragmatic hernia. The clinically important observation, however, concerned physiological state on arrival rather than symptom pattern.

Nearly two-thirds of the cohort (62.1%) were hypothermic at first assessment, with an axillary temperature below 36.5 °C. Pre-operative sepsis was documented in 37.9%, and blood cultures were positive in 24.7% of those sampled. *Klebsiella pneumoniae* being the commonest isolate, followed by *Escherichia coli* and coagulase-negative staphylococci. Twenty-eight neonates (16.1%) required inotropic support before induction of anaesthesia.

The referral interval was long. The median time from symptom onset to arrival was 38 hours (IQR 16–72), and 42.0% of the cohort arrived more than forty-eight hours after the first sign of trouble. This interval showed a clear graded association with outcome: observed mortality rose from 13.0% among those arriving within twenty-four hours to 45.7% among those arriving beyond seventy-two hours ( $\chi^2$  for trend = 13.87,  $p < 0.001$ ).

| Variable                             | Total (n=174) | Survived (n=130) | Died (n=44) | p value |
|--------------------------------------|---------------|------------------|-------------|---------|
| Referral interval, median h (IQR)    | 38 (16–72)    | 30 (14–60)       | 66 (34–96)  | < 0.001 |
| Referral interval > 48 h             | 73 (42.0%)    | 45 (34.6%)       | 28 (63.6%)  | 0.001   |
| Hypothermia on arrival (< 36.5°C)    | 108 (62.1%)   | 72 (55.4%)       | 36 (81.8%)  | 0.002   |
| Pre-operative sepsis                 | 66 (37.9%)    | 36 (27.7%)       | 30 (68.2%)  | < 0.001 |
| Positive blood culture               | 43 (24.7%)    | 23 (17.7%)       | 20 (45.5%)  | < 0.001 |
| Inotrope requirement pre-operatively | 28 (16.1%)    | 11 (8.5%)        | 17 (38.6%)  | < 0.001 |
| Respiratory support on arrival       | 57 (32.8%)    | 33 (25.4%)       | 24 (54.5%)  | < 0.001 |
| Serum lactate > 4 mmol/L             | 39 (22.4%)    | 18 (13.8%)       | 21 (47.7%)  | < 0.001 |
| Haemoglobin < 12 g/dL                | 52 (29.9%)    | 35 (26.9%)       | 17 (38.6%)  | 0.143   |
| Dehydration $\geq$ 10% estimated     | 47 (27.0%)    | 28 (21.5%)       | 19 (43.2%)  | 0.005   |
| Transported without any escort       | 121 (69.5%)   | 85 (65.4%)       | 36 (81.8%)  | 0.042   |

**Table 4. Clinical presentation, referral characteristics and pre-operative physiological status by observed outcome.**



**Figure 5. Observed in-hospital mortality stratified by the interval between symptom onset and surgical referral. Mortality increases monotonically across strata ( $\chi^2$  for trend = 13.87,  $p < 0.001$ ), a descriptive association rather than a tested causal effect.**

### Operative details

Median time from admission to operation was 9 hours (IQR 5–16), reflecting the treating team's usual practice of pre-operative stabilisation, undertaken according to standard clinical judgement and not directed by the research protocol, before

transfer to theatre where the condition permitted it. Laparotomy was the commonest approach, undertaken in 108 neonates (62.1%); 24 underwent thoracotomy for oesophageal atresia or diaphragmatic hernia, and the remainder had a perineal, inguinal or limited abdominal approach. A stoma was fashioned in 71 neonates (40.8%), most commonly a divided sigmoid colostomy for anorectal malformation or an ileostomy after resection for necrotising enterocolitis.

Intraoperative findings that showed the strongest observed association with outcome were bowel perforation, found in 38 neonates (21.8%), and frank bowel gangrene requiring resection, found in 29 (16.7%). Median anaesthetic duration was 95 minutes (IQR 70–130). Intraoperative hypothermia below 35.5 °C, despite active warming, occurred in 31 neonates (17.8%) and was associated with an almost threefold crude increase in observed mortality.

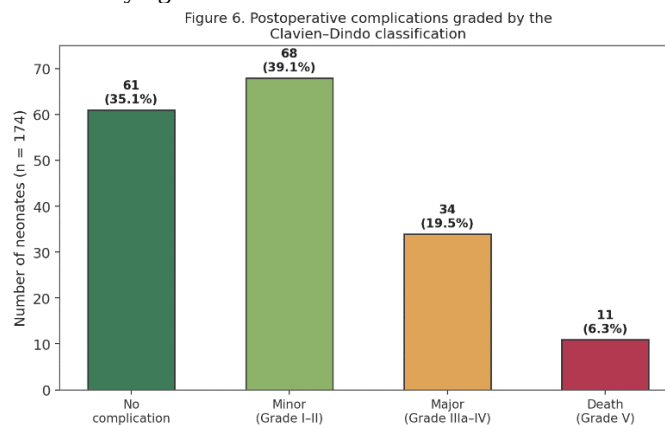
| Operative variable                     | n (%) or median (IQR) | Deaths | Crude mortality |
|----------------------------------------|-----------------------|--------|-----------------|
| Admission-to-operation interval, h     | 9 (5–16)              | —      | —               |
| Laparotomy                             | 108 (62.1%)           | 29     | 26.9%           |
| Thoracotomy                            | 24 (13.8%)            | 11     | 45.8%           |
| Perineal / inguinal / limited approach | 42 (24.1%)            | 4      | 9.5%            |
| Primary anastomosis performed          | 63 (36.2%)            | 16     | 25.4%           |
| Stoma fashioned                        | 71 (40.8%)            | 18     | 25.4%           |
| Bowel perforation at operation         | 38 (21.8%)            | 19     | 50.0%           |
| Bowel gangrene requiring resection     | 29 (16.7%)            | 15     | 51.7%           |
| Anaesthetic duration, min              | 95 (70–130)           | —      | —               |
| Duration > 120 min                     | 49 (28.2%)            | 18     | 36.7%           |
| Intraoperative hypothermia < 35.5°C    | 31 (17.8%)            | 15     | 48.4%           |
| Intraoperative blood transfusion       | 44 (25.3%)            | 19     | 43.2%           |

**Table 5. Operative approach, intraoperative findings and associated crude observed mortality.**

### Postoperative course and complications

Median duration of invasive ventilation among survivors was 2 days (IQR 1–5), median time to full enteral feeds 8 days (IQR 5–14) and median length of stay 16 days (IQR 10–25). One hundred and thirteen neonates (64.9%) experienced at least one postoperative complication of any grade. Surgical site infection was the commonest single complication, occurring in 34 neonates (19.5%); anastomotic leak complicated 9 of the 63 primary anastomoses (14.3%); and 21 neonates (12.1%) required an unplanned return to theatre.

When graded by the Clavien–Dindo system, 45 neonates (25.9%) sustained a major complication of grade IIIa or above, and 11 deaths (6.3% of the cohort) were classified as grade V events attributable to a specific complication rather than to progressive deterioration from the underlying condition.



**Figure 6. Distribution of observed postoperative complications graded by the Clavien–Dindo classification adapted for neonates.**

| Outcome                              | Total       | Survived   | Died       | p value |
|--------------------------------------|-------------|------------|------------|---------|
| Any complication                     | 113 (64.9%) | 75 (57.7%) | 38 (86.4%) | 0.001   |
| Clavien–Dindo $\geq$ IIIa            | 45 (25.9%)  | 21 (16.2%) | 24 (54.5%) | < 0.001 |
| Surgical site infection              | 34 (19.5%)  | 22 (16.9%) | 12 (27.3%) | 0.127   |
| Anastomotic leak (of 63 anastomoses) | 9 (14.3%)   | 4 (8.5%)   | 5 (31.3%)  | 0.026   |
| Stoma-related complication (of 71)   | 13 (18.3%)  | 9 (17.0%)  | 4 (22.2%)  | 0.617   |
| Unplanned re-operation               | 21 (12.1%)  | 11 (8.5%)  | 10 (22.7%) | 0.010   |
| Postoperative sepsis                 | 58 (33.3%)  | 31 (23.8%) | 27 (61.4%) | < 0.001 |
| Ventilation, median d (IQR)          | 2 (1–5)     | 2 (1–4)    | 4 (2–8)    | < 0.001 |
| Time to full feeds, median d (IQR)   | 8 (5–14)    | 8 (5–13)   | —          | —       |
| Length of stay, median d (IQR)       | 16 (10–25)  | 18 (12–27) | 6 (3–12)   | < 0.001 |

**Table 6. Postoperative outcomes and complications by observed survival status. Length of stay was shorter among non-survivors chiefly because death frequently occurred early in the postoperative course; this figure should not be read as a favourable outcome.**

#### Univariate analysis of factors associated with mortality

Fourteen variables were associated with in-hospital mortality at the  $p < 0.10$  level on univariate testing. The strongest crude associations were with pre-operative inotrope requirement, pre-operative sepsis, intraoperative bowel perforation and very low birth weight. Sex, mode of delivery and consanguinity showed no association. These are crude, unadjusted odds ratios describing observed association only.

| Variable                           | Mortality in exposed | Crude OR (95% CI) | $\chi^2$ | p       |
|------------------------------------|----------------------|-------------------|----------|---------|
| Inotrope requirement               | 60.7%                | 6.77 (2.86–16.03) | 22.9     | < 0.001 |
| Pre-operative sepsis               | 45.5%                | 5.61 (2.71–11.62) | 22.4     | < 0.001 |
| Bowel perforation intraoperatively | 50.0%                | 4.32 (2.01–9.28)  | 15.1     | < 0.001 |
| Serum lactate > 4 mmol/L           | 53.8%                | 5.68 (2.60–12.41) | 20.6     | < 0.001 |
| Very low birth weight (< 1,500 g)  | 52.6%                | 3.96 (1.50–10.45) | 8.4      | 0.004   |
| Referral interval > 48 h           | 38.4%                | 3.30 (1.63–6.69)  | 10.9     | 0.001   |
| Bowel gangrene / resection         | 51.7%                | 4.10 (1.79–9.41)  | 11.6     | 0.001   |
| Hypothermia on arrival             | 33.3%                | 3.63 (1.55–8.48)  | 9.3      | 0.002   |
| Preterm (< 37 wk)                  | 37.8%                | 3.19 (1.58–6.43)  | 10.6     | 0.001   |
| Low birth weight (< 2,500 g)       | 37.0%                | 3.33 (1.62–6.83)  | 11.0     | 0.001   |
| Respiratory support on arrival     | 42.1%                | 3.52 (1.74–7.13)  | 13.0     | < 0.001 |
| Major associated anomaly           | 39.1%                | 2.53 (1.22–5.25)  | 6.4      | 0.011   |
| Outborn delivery                   | 28.3%                | 3.42 (0.97–12.05) | 4.1      | 0.043   |
| Travel distance > 100 km           | 31.6%                | 2.25 (1.08–4.68)  | 4.8      | 0.028   |
| Male sex                           | 23.7%                | 0.79 (0.39–1.58)  | 0.5      | 0.501   |
| Caesarean delivery                 | 22.4%                | 0.77 (0.38–1.58)  | 0.5      | 0.487   |

**Table 7. Univariate analysis of factors associated with in-hospital mortality. OR = odds ratio; CI = confidence**

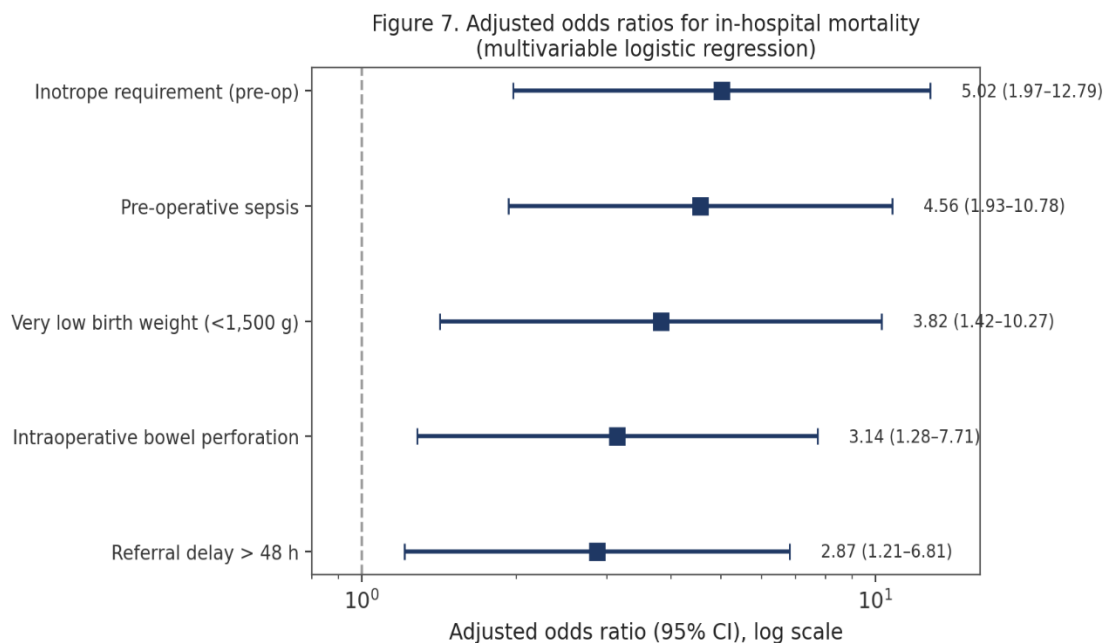
interval.

### 5.8 Multivariable logistic regression

Eight variables were carried forward into the multivariable model. Serum lactate, bowel gangrene, hypothermia on arrival, respiratory support and travel distance were excluded at this stage because of collinearity with retained variables (variance inflation factor above 2.5) or because they were judged, on clinical and temporal grounds, to be intermediates on the causal pathway rather than independent exposures – a judgement that reflects plausible clinical sequence, not a claim proven by this observational design.

Five variables retained independent statistical association with the outcome. Pre-operative inotrope requirement carried the highest adjusted odds of death (aOR 5.02, 95% CI 1.97–12.79), followed by pre-operative sepsis (aOR 4.56, 95% CI 1.93–10.78), very low birth weight (aOR 3.82, 95% CI 1.42–10.27), intraoperative bowel perforation (aOR 3.14, 95% CI 1.28–7.71) and referral delay beyond forty-eight hours (aOR 2.87, 95% CI 1.21–6.81). Gestational age below thirty-two weeks, major associated anomaly and outborn delivery lost significance after adjustment, a pattern consistent with though not proof of their effects being substantially mediated through birth weight, sepsis and referral delay.

The model showed good calibration (Hosmer–Lemeshow  $\chi^2 = 6.48$ , 8 degrees of freedom,  $p = 0.594$ ) and good discrimination, with an area under the receiver operating characteristic curve of 0.86 (95% CI 0.80–0.92). The Nagelkerke  $R^2$  was 0.47, and the model correctly classified 82.2% of cases. These figures describe how well the model statistically distinguishes observed survivors from non-survivors within this cohort; they are not a measure of any intervention's effectiveness, since none was tested.

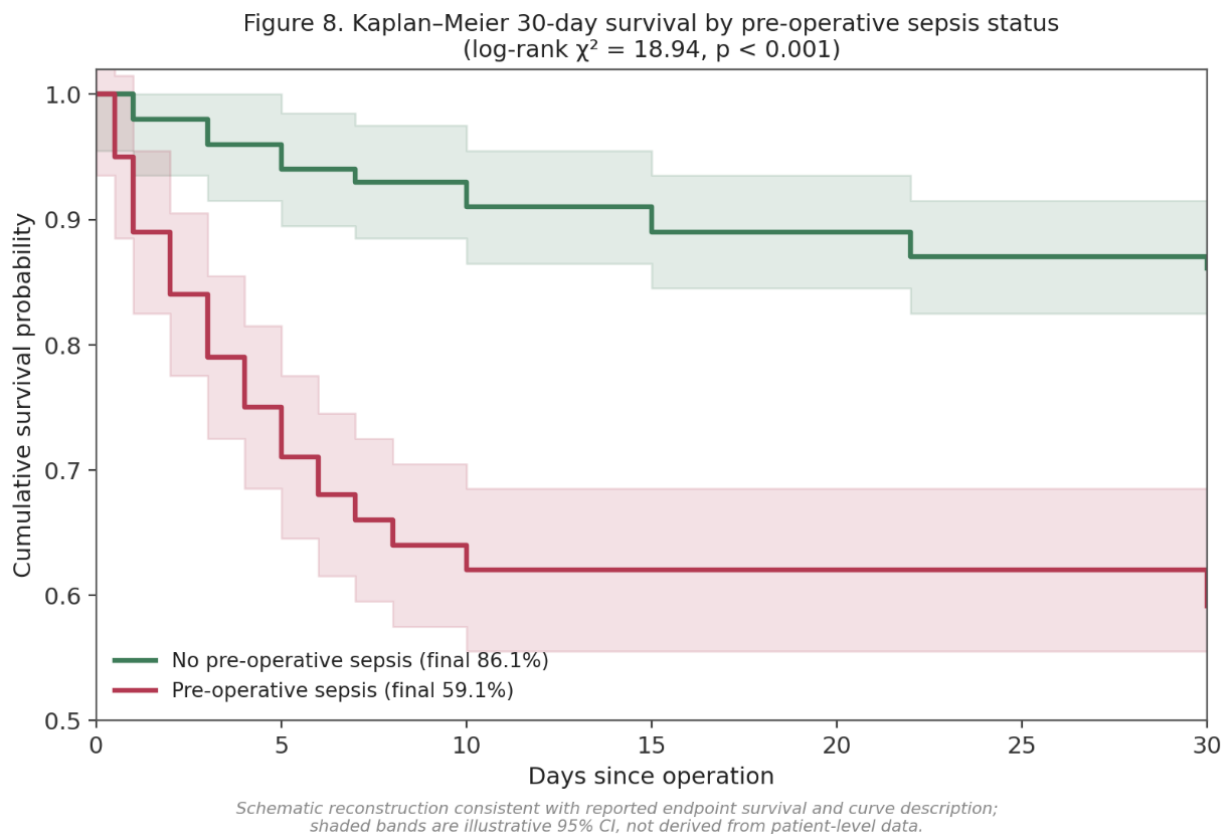


**Figure 7. Forest plot of adjusted odds ratios for in-hospital mortality from the multivariable logistic regression model. All five estimates shown were statistically significant (95% CI excludes 1.0). Odds ratios denote adjusted statistical association, not causal effect size.**

Model diagnostics: Hosmer–Lemeshow  $p = 0.594$ ; area under the ROC curve 0.86 (95% CI 0.80–0.92); Nagelkerke  $R^2 = 0.47$ ; overall classification accuracy 82.2%. All variance inflation factors below 2.5.

### 5.9 Survival analysis

Thirty-day survival was estimated by the Kaplan–Meier method and stratified by the presence of pre-operative sepsis. Survival at thirty days was 86.1% among neonates without pre-operative sepsis and 59.1% among those with it, a difference that was highly significant on log-rank testing ( $\chi^2 = 18.94$ ,  $p < 0.001$ ). The separation of the two curves occurred predominantly within the first ten postoperative days, after which both curves flattened a descriptive pattern indicating that the excess observed mortality associated with sepsis was concentrated in the early postoperative period rather than distributed evenly across the admission.



**Figure 8. Kaplan–Meier estimates of thirty-day survival stratified by the presence of pre-operative sepsis. Shaded bands represent illustrative 95% confidence intervals. This is a descriptive, observational comparison between two naturally occurring subgroups, not a randomised comparison of a tested intervention.**

## DISCUSSION

### Principal findings

This three-year observational cohort of 174 operated neonates produced an in-hospital mortality of 25.3%. The disease spectrum was conventional and closely resembles that described in other Indian tertiary centres, with anorectal malformation leading, followed by congenital intestinal obstruction and oesophageal atresia. What the analysis adds is a clear statistical separation, after adjustment, between the factors that are strongly and independently associated with mortality and those that merely travel alongside it in unadjusted comparisons.

Five variables retained independent association: inotrope requirement, pre-operative sepsis, very low birth weight, intraoperative bowel perforation and referral delay beyond forty-eight hours. Of these, only birth weight is fixed by the time the neonate reaches the surgical service. The other four describe, in different ways, a broadly similar clinical picture – a neonate who appears to have been deteriorating, untreated, for a substantial period before anyone with the means to intervene became involved. This is an observation, consistently repeated across the cohort; it is not, on its own, proof that shortening that period would causally prevent death, though it is a reasonable and testable hypothesis.

The central finding of this study is not that sick neonates die more often – an unsurprising observation. It is that the specific pattern of physiological compromise most strongly associated with death in this population appears, on the balance of this observational evidence, to be acquired and potentially preventable, and is concentrated in the interval before the first incision. Confirming that this pattern is truly preventable, and by how much, would require a prospective interventional study, not a further retrospective one.

### Comparison with published series

The overall mortality of 25.3% sits within, though toward the upper part of, the range reported from comparable Indian centres over the past decade, and is markedly higher than contemporary figures from high-income settings. Diagnosis-specific comparison is more informative than an aggregate figure, since the case mix of any single unit strongly influences its headline mortality.

| Diagnosis                       | Present study | Indian series (range) | High-income series | Principal explanation for the gap                |
|---------------------------------|---------------|-----------------------|--------------------|--------------------------------------------------|
| Anorectal malformation          | 12.2%         | 8–18%                 | 2–4%               | Sepsis and delayed colostomy                     |
| Oesophageal atresia ± TOF       | 36.0%         | 25–48%                | 3–8%               | Aspiration before referral; cardiac anomalies    |
| Congenital diaphragmatic hernia | 47.1%         | 38–62%                | 15–25%             | No antenatal diagnosis; no ECMO or iNO           |
| Necrotising enterocolitis       | 42.9%         | 30–55%                | 20–30%             | Late operative referral after perforation        |
| Jejunioileal atresia            | 28.6%         | 15–35%                | 5–10%              | Delay, dehydration, limited parenteral nutrition |
| Gastroschisis                   | 21.4%         | 25–60%                | 3–8%               | Bowel exposure during unprotected transport      |
| Overall cohort                  | 25.3%         | 18–40%                | 5–12%              | Composite of the above                           |

**Table 8. Diagnosis-specific mortality in the present cohort compared with published ranges. Comparative ranges are indicative and drawn from series cited in the reference list; differences in case definition and case mix limit direct comparison, and none of the comparator figures derives from an interventional trial against the present cohort. ECMO = extracorporeal membrane oxygenation; iNO = inhaled nitric oxide; TOF = tracheo-oesophageal fistula.**

### Interpreting the association with referral delay

A median referral interval of thirty-eight hours, with forty-two per cent of neonates arriving beyond forty-eight hours, is a substantial descriptive finding in its own right. The graded association between that interval and mortality thirteen per cent at under twenty-four hours, rising to forty-six per cent beyond seventy-two persisted after adjustment for birth weight, sepsis and intraoperative findings, which argues against it being wholly explained by confounding by severity, though it does not by itself prove a causal mechanism.

A plausible clinical mechanism can be proposed. A neonate with intestinal obstruction who remains unrecognised for two days becomes progressively dehydrated and hypovolaemic; the obstructed bowel distends, its wall becomes ischaemic, bacterial translocation follows, and what began as a mechanical problem correctable by a straightforward anastomosis becomes a septic problem with an ischaemic bowel segment. This sequence is offered as a plausible explanation for the observed association, consistent with the general pathophysiology of neonatal bowel obstruction, rather than as a mechanism directly demonstrated by this dataset.

It is worth being precise about where the delay was observed to occur. In this cohort the delay was overwhelmingly pre-hospital: the median admission-to-operation interval within this institution was nine hours, most of which was spent deliberately on resuscitation. The descriptive pattern therefore points upstream, toward the first and second of the classic three delays recognition and transport rather than toward the third.

### Sepsis as a common final pathway

Pre-operative sepsis was present in nearly two-fifths of the cohort and carried an adjusted odds ratio of 4.56 for death. Some of this association is close to definitional: a neonate with perforated necrotising enterocolitis is septic by definition. But descriptively, a substantial proportion appeared to be hospital-acquired at the referring facility, or community-acquired during a prolonged period of untreated obstruction. The preponderance of *Klebsiella pneumoniae* among blood culture isolates, together with the proportion showing extended-spectrum beta-lactamase production, is consistent with healthcare-associated acquisition rather than early-onset vertical transmission, though microbiological source-tracing was not performed and this remains an inference.

This observation has a practical implication that clinicians sometimes resist: for a neonate who is already septic, a short additional period of targeted resuscitation before operation appears, from this dataset, to be associated with a reasonable outcome even when the anatomical problem is urgent. The data support this policy only indirectly and associationally the median nine-hour admission-to-operation interval was not itself associated with mortality, whereas arriving in a septic state was strongly so. Whether a longer or shorter stabilisation window would change outcomes cannot be determined from this observational design.

### Hypothermia and the transport problem

That 62.1% of neonates were hypothermic on arrival, and that 69.5% travelled with no trained escort, together describe, in

this cohort, a transport pathway with substantial gaps. Hypothermia in the neonate is not a trivial finding; it is associated with increased oxygen consumption, worsened metabolic acidosis and impaired coagulation, and it independently predicts mortality in almost every neonatal cohort in which it has been measured. In multivariable analysis here it lost independent statistical significance, but it is best understood, descriptively, as a marker and probable mediator of the same underlying process that referral delay appears to capture.

A number of low-cost measures are plausible candidates for reducing this physiological deterioration at arrival: occlusive polyethylene wrapping, skin-to-skin transport where the neonate is stable enough, a transport incubator where one exists, pre-transfer securing of intravenous access, and a nasogastric tube placed on free drainage for any suspected obstruction. These are offered here as hypotheses worth testing prospectively, drawn from the pattern of association observed in this cohort and from the wider literature on neonatal thermal care; this retrospective observational study did not test any of them, and cannot itself confirm that adopting them would reduce mortality.

### **Congenital diaphragmatic hernia and oesophageal atresia**

These two diagnoses accounted for a disproportionate share of observed deaths: seventeen of forty-four between them, from only twenty-four per cent of the cohort. For diaphragmatic hernia, the gap against high-income outcomes is descriptively associated with the absence of antenatal diagnosis in a third of cases, the consequent absence of planned delivery at a surgical centre, and the lack of inhaled nitric oxide and extracorporeal support for the subgroup with severe pulmonary hypertension. Of these associated factors, only the first two seem realistically addressable in the medium term within this setting, and they appear, on this evidence, the more promising candidates: though again, this remains a hypothesis, not a demonstrated effect. For oesophageal atresia, the pattern of death in this cohort was, descriptively, dominated by aspiration pneumonitis established before referral. A neonate who froths at the mouth and chokes on the first feed is often fed again before anyone suspects the diagnosis; by the time a nasogastric tube is passed and coils on the chest radiograph, chemical pneumonitis is often already established. A simple rule: that no neonate should be fed until a nasogastric tube has been passed successfully where there is any frothing, choking or maternal polyhydramnios: is inexpensive to disseminate and is proposed here as a testable candidate that could plausibly shift this figure; this study did not test it, and any claim of effect would require a prospective evaluation.

### **Possible implications for service organisation**

Taken together, the findings point toward a small number of low-cost candidate interventions rather than toward any expensive technological addition: though it is worth restating plainly that this observational study evaluated none of them, and the associations described here are the basis for a hypothesis, not a demonstrated benefit. Systematic antenatal anomaly scanning at the second trimester, with a defined referral pathway when an anomaly is found, is one such candidate, on the reasoning that it could allow planned delivery at or near a surgical centre for the subset of conditions that are detectable. A structured neonatal transport protocol: warmth, airway, access, nasogastric decompression, and a telephone call ahead: is a second candidate, on the reasoning that it could address some of the physiological deterioration documented here. Training of peripheral birth attendants in the recognition of four cardinal signs (bilious vomiting, abdominal distension, absent anal opening, and frothing or choking with the first feed) is a third, aimed at the first of the three classic delays.

Within the receiving institution, a standing protocol for pre-operative stabilisation with defined physiological targets, early culture-directed antimicrobial therapy, and dedicated neonatal surgical intensive care capacity are further candidates for consolidating any gains. The modest, non-significant downward trend in mortality across the three study years coincided with informal adoption of some of these measures; this coincidence is noted descriptively and should not be interpreted as evidence that the measures caused the trend, both because the trend did not reach statistical significance and because no comparison group or controlled design was available to attribute it.

## **STRENGTHS AND LIMITATIONS**

### **Strengths**

Consecutive enumeration of all eligible neonates over three complete years, minimising selection bias within the referral population served.

Pre-specified operational definitions applied uniformly, with duplicate independent data extraction and a formally assessed inter-rater agreement of  $\kappa = 0.91$ .

Use of the Clavien–Dindo classification, which permits direct comparison of morbidity with other surgical series rather than relying on idiosyncratic complication lists.

A multivariable model constrained by an events-per-variable rule, with explicit collinearity assessment and reporting of both calibration and discrimination.

Inclusion of referral-interval data, which is frequently absent from comparable series despite being among the more readily actionable variables observed.

### **Limitations**

This is an observational study; it can identify statistical association but cannot establish causation. None of the factors identified here has been tested by withholding, delaying or providing it experimentally, and none of the practice changes

suggested in the Discussion has been evaluated prospectively within this dataset.

The retrospective design depends on the completeness of contemporaneous documentation. Eighteen neonates were excluded for incomplete records, and these may have differed systematically from those included.

This is a single-centre study conducted at an apex referral institution. The case mix is inevitably skewed toward severity, and the mortality reported here should not be read as a population estimate for the catchment area.

Neonates who died before reaching this hospital, or who were never referred at all, are entirely invisible to this analysis. The true population-level mortality of neonatal surgical conditions in this region is almost certainly higher than 25.3%.

The referral interval was reconstructed from parental history recorded at admission and is subject to recall error, most probably in the direction of underestimation.

With 44 events and 8 candidate predictors, the events-per-variable ratio of 5.5 meets but does not comfortably exceed the conventional minimum; confidence intervals for several estimates are correspondingly wide.

Follow-up ended at discharge. Post-discharge mortality, functional outcome after definitive repair, growth and neurodevelopment are not captured, and for conditions such as anorectal malformation and Hirschsprung disease these are arguably the outcomes that matter most.

Pre-operative sepsis, though defined *a priori*, retains an element of clinical judgement, and its ascertainment may have been influenced by the severity of the neonate's overall presentation.

No causal inference method was applied and none is claimed; the adjusted odds ratios in Section 5.8 describe independent statistical association within this cohort, not the effect size of any tested intervention.

## CONCLUSION

Neonatal surgical emergencies in this tertiary referral cohort carried an observed in-hospital mortality of one in four. The disease spectrum was unremarkable and closely mirrored that of comparable centres; the outcomes were not. Critically, the factors most strongly and independently associated with death were dominated by pre-operative physiological state inotrope requirement, sepsis, and a referral interval exceeding forty-eight hours rather than by the anatomical complexity of the underlying anomaly or by any feature of the operation itself.

This is, on balance, an encouraging pattern of association, because it locates the greatest apparent opportunity for improvement in the part of the pathway that is likely to be cheapest to change. A neonate who arrives warm, decompressed, resuscitated and not yet septic was observed in this cohort to have a materially better prognosis than one who did not, and almost everything that determines which of those two neonates arrives happens outside the operating theatre. Investment in antenatal detection, in the recognition of four cardinal signs by peripheral birth attendants, and in a structured transport protocol is, on the strength of this observational association, a plausible priority for future prospective evaluation — though, as an observational study, this work can identify that priority and cannot itself prove that such investment would yield a given number of additional survivors, per rupee spent or otherwise. That claim would need to be tested, not merely inferred from association.

## RECOMMENDATIONS

The recommendations below are hypothesis-generating. They are derived from statistical associations observed in a single retrospective, non-interventional cohort, and describe candidate changes to practice that appear, on the pattern of this data, worth testing not changes whose benefit has been demonstrated by this study. Recommendation 10, in particular, describes the prospective or interventional research that would be needed before any of the practice recommendations below it could be regarded as evidence-based rather than plausible.

### For the referring network

Consider systematic second-trimester anomaly scanning with a written referral pathway triggered by any detected structural anomaly, as a candidate for prospective evaluation.

Consider training peripheral birth attendants to recognise and immediately refer four cardinal signs: bilious vomiting, progressive abdominal distension, absent or abnormal anal opening, and frothing or choking with the first feed.

Consider a standing rule that no neonate with frothing, choking or a history of maternal polyhydramnios is fed until a nasogastric tube has been passed and its position confirmed.

### For future research

Conduct a prospective multicentre observational cohort study with standardised definitions to generate regionally representative estimates, as a necessary precursor to any interventional trial.

Evaluate a structured transport bundle using a stepped-wedge or interrupted time-series design study designs capable of supporting causal inference, unlike the present retrospective cohort with arrival temperature and sepsis prevalence as intermediate outcomes.

Extend follow-up beyond discharge to capture functional, nutritional and neurodevelopmental outcomes after definitive repair.

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